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THE X-RAY DIAGNOSIS OF CHEMICAL AND INDUSTRIAL MATERIALS, AND A NEW TYPE OF BIOLOGICAL AND MEDICAL DIAGNOSIS[1]

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IT is an inevitable tendency for so versatile and powerful a tool as X-radiation to find continually new fields of useful application. In the slightly more than three decades of history of X-ray science the outstanding phase has been in medical diagnosis and therapy, while in a few academic laboratories of physics, the nature of the radiation, its relationship to light, its wave lengths, and the fundamental laws which govern its generation have been quietly studied. And now in these days the world is awakened suddenly to the fact that chemistry and industry are finding X-rays so marvelously helpful in the solution of innumerable complexities and difficulties that, upon the basis of such experience, a great new X-ray science is now able to come back to the parent medical science and point the way for new applications hitherto undreamed of. It is the purpose of this paper to review briefly the achievements of less than five years in the study of chemical and industrial materials, even to the devising of new manufacturing technic upon the sole basis of X-ray information, and to show how the experimental methods and the generalizations from the results of these investigations may be turned to remarkable advantage in the study of biological materials and the solution of medical problems.

There are really four phases to this new chemical and industrial science of X-rays, two of which have their exact counterpart in medical applications. These are as follows:

(1) The spectrometric identification and wave length measurement of X-rays generated from various substances used as targets in X-ray tubes.

(2) The study of the direct chemical and electrical effects in inorganic materials, corresponding to roentgenology or X-ray therapy.

(3) The examination of materials for gross structure, inhomogeneities, imperfections, etc., corresponding to radiography or applications in medical diagnosis.

(4) The analysis of solids and liquids of every description for *ultimate* or fine structure.

I. SPECTROSCOPY

The branch of X-ray science which is concerned with the measurement of unknown wave lengths of X-rays generated from substances used as targets has been applied, in chemistry, principally to the discovery of new elements (within the past two years hafnium, No. 72, in Denmark,

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illinium, No. 61, at the University of Illinois, masurium, No. 43, and rhenium, No. 75, in Germany), and to qualitative and quantitative analysis of mixtures, particularly of rare metals. These depend upon the fact, of course, that, above definite voltage limits, every chemical element produces X-rays with wave lengths which are characteristic of it alone. The law, discovered by Moseley, that the square roots of the frequencies for a given X-ray spectral line are a linear function of atomic members of the elements from hydrogen, 1, to uranium, 92, has done more perhaps than any other discovery to produce a satisfactory picture of the structure of atoms, which are built up in definite and continuous steps from the simple unit structure of hydrogen. This is an exact science, so that the roentgenologists who determine dosage most scientifically and accurately in terms of wave lengths and spectral intensity distribution, utilize the ionization spectrometer or photographic spectrograph. In the chemical laboratory the spectrometer has not displaced the balance as an analytical tool, but it is proving a valuable auxiliary equipment, particularly for mixtures which can be separated only with greatest difficulty, since every constituent discloses its presence in X-ray analysis independent of the state or complexity of the mixture. Precision work has demonstrated that the nature of the chemical combination of an element may be ascertained—for example, sulfur whether present as such, as sulfide, sulfite, sulfate, etc.—since the characteristic wave lengths depend slightly upon this.

II. DIRECT CHEMICAL AND ELECTRICAL EFFECTS

An adequate explanation of the mechanism of the action of X-rays on biological systems is now being sought with renewed interest by experiments on simple chemical and colloidal systems. Many facts in this general category are familiar to radiologists, since various chemical and electrical phenomena are utilized in the measurement of dosage. These may be enumerated in part as follows:

1. Ionization of gases.

2. The lowering of the disruptive discharge potential.

3. The increase in electrical conductivity of solid dielectrics (sulfur, amber, rubber, bakelite, etc.).

4. Decrease in resistance of selenium.

5. Effect on the potential of anodically polarized electrodes.

6. Effect on photographic plate.

7. Photochemical reactions (starch to dextrin, inversion of cane sugar, hydrogen peroxide formation in water, decomposition of organic compounds, reduction of potassium iodate and permanganate, oxidation of sulfurous acid, etc.).

8. Fluorescence in chemical compounds and minerals.

9. Coloration of stones and minerals (including the production of "antique" violet glass very rapidly).

10. Flocculation or stabilization of colloids. This is of great importance from the standpoint of biological systems. Crowther and Fairbrother in an important paper have shown very recently that colloidal sols of iron and copper (cationic or positive metal colloids) are rendered less stable, and precipitated, and sols of silver and gold (negative colloids) more stable by the action of a carefully measured X-ray dose of 75,000 *c*-units. A change in electric charge by ionization and ejection of electrons from the colloidal particles does not account simply for these results, but the electrical double layer around each particle must be considered.

11. Increase upon irradiation of activity of platinum catalysts in the contact method of preparing sulfur trioxide and sulfuric acid from sulfur dioxide and oxygen (ex-

periments by the writer). In this case the economic possibilities of increasing yields by means of X-rays are very promising.

12. Inhibition of corrosion of metals.

13. Transformation of unstable crystalline modifications of chemical compounds, such as one form of sulfur trioxide, to a stable form.

These examples might be multiplied, but they serve to show that the therapeutic and biological effects of radiation on single cells, tissues, and whole organisms have their chemical and industrial analogies. Because the latter type of experiments are more easily controlled and interpreted in the absence of the variable of life, they are serving to clarify many of the difficult biological results. Evidence is rapidly accumulating that the chemical and biological effects are to be ascribed primarily to corpuscular β-rays, or high speed electrons, which are ejected from solids and liquid molecules, as they are in gases, by the primary X-rays. New and extremely valuable contributions in this most difficult field may be anticipated. Many of these will have practical chemical and industrial importance, and, in addition, they will assist materially in a growing scientific understanding of reactions in therapy. For this, after all, is the finest and most altruistic contribution which these new chemical and industrial researches can make.

III. RADIOGRAPHY

1. While X-rays penetrate matter opaque to light, they are absorbed in accordance with a simple exponential law. Any inhomogeneity or defect in a material will have a different density and absorbing power for X-rays than the main body of material. Hence, the X-rays which pass through a material will have varying intensity, and, when they strike a photographic plate, a "shadowgraph" of the specimen will be registered, which may also be visually observed on a fluorescent screen. Observations of bones in the body and teeth are, of course, the most familiar examples of radiography. The experimental technic is comparatively simple since it consists merely in placing an object to be radiographed between an X-ray tube and a photographic plate. There are many details, however, which require long experience. The higher the voltage applied to the X-ray tube, the shorter is the effective wave length and the more penetrating the beam. The maximum thickness of steel which may be radiographically examined is 4 inches. Further advances can come only with newly designed X-ray tubes capable of withstanding higher than 300,000 volts. There are many important, interesting, and useful applications of this branch of X-ray science. The following are some which have been found in America.

Radiographic Applications

1. Metal castings for internal gas cavities, sand and slag inclusions, pipe cavities, porosity, cracks, metal segregation.

2. Medical and dental diagnosis; identifications of persons; shoe fitting.

3. Welds, for soundness.

4. Coal, control of washing process.

5. Minerals, classification.

6. Rubber, symmetry of golf-ball centers, adhesion to cords in tires, inspection of reclaimed rubber for nails, heavy metal content.

7. Insulated wire inspection.

8. Grenades and shells, filling.

9. Wood used in airplanes, etc., for cracks, wormholes, knots.

10. Hidden wires and pipes in walls; mystery packages; contraband.

11. Internal diameters of metal pipes and capillaries, height of capillary rise of liquids, clogged gasoline feed lines.

12. Position of electrodes in vacuum tubes.

13. Old paintings, examination for retouching and superimposed pictures.

14. Glass, heavy metal content.

15. Pigments, partial identification.

16. Swiss cheese, size and location of holes.

Particular attention is called to the remarkable developments in casting and welding technic which have been made possible by radiography. The performance of equipment subjected to high temperatures and high pressures, such as in oil stills and power plants, is thus assured. In Figure 1 a typical radiograph of an internally defective steel casting is reproduced.

IV. THE FINE STRUCTURE OF MATERIALS

1. X-rays and Crystals

The examination of materials for ultimate structure and constitution depends upon the fact that crystals are three-dimensional diffraction gratings for X-rays. Crystals are built up of parallel planes upon which lie the atoms, and these planes are spaced from each other at a distance which is entirely comparable with the wave length of X-rays. Thus, a structure which appears homogeneous to the eye will disclose a fine structure to the microscope, which, in turn, will show subdivision in the ultra-violet microscope, and one of these subdivisions will diffract X-rays in a way which indicates that it, in turn, is built of ultimate crystal units. Thus, when a beam of X-rays defined by small pinholes passes through a single crystal grain of iron, the result is a pattern of sharp spots (Fig. 2) on a photographic plate placed behind the crystal. In every direction through the grain are parallel planes of atoms with a certain spacing. Each set of planes picks out from the X-ray beam impinging upon this set at a certain angle a ray of a definite wave length, λ, which is reflected in accordance with the simple Bragg law $n\lambda = 2\,d \sin \theta$. This diffraction pattern upon analysis proves that the smallest subdivision which is still crystalline iron is a cube with an atom of iron at each corner and one at the center and with an edge length of 2.86×10^{-8} cm. This minute unit cell multiplied in all directions produces the visible crystal grain. With such a fundamental relationship between matter and X-radiation it is evident that crystals of known unit cell dimensions may be used as gratings to analyze beams of X-rays, and, *vice versa*, X-rays of known wave lengths may be used to analyze the unknown structure of crystals. Even in liquids, colloidal gels, and other so-called amorphous substances without vestige of crystal faces or of geometric arrangement in space, the fact remains that molecules or aggregates of molecules in disordered motion cannot approach each other nearer than a certain limit. This distance of closest approach may be ascertained from the simple X-ray diffraction patterns of one or two broad rings. X-rays are a versatile tool and the information which they vouchsafe concerning fine structures of materials is astonishingly complete, as shown by the following enumeration:

Types of Diffraction Information:

1. Crystalline or amorphous.
2. Macrocrystalline or colloidal.
3. Lattice structure, atomic and molecular arrangement and dimensions for crystals, distances of nearest approach of molecules or aggregates in liquids, gels, etc.
4. Chemical identity (compound, mixture, adsorption complex, solid solution), purity, phase structure.
5. Transformations and allotropic modifications.
6. Chemical change, aging.
7. Single crystal or aggregate.
8. Random or fibered aggregate.
9. Degree of fibering deformation and quantitative analysis of mechanism of deformation; effects of fabrication—rupture,

Fig. 1. Radiograph of cast steel, showing imperfections. *(Courtesy of Dr. H. H. Lester.)*

Fig. 2. Typical pattern for a single crystal of iron.

rolling, drawing, torsion, impact, complex deforming forces, electrodeposition, annealing, directional properties.

10. Grain size.

11. Internal strain.

12. Differentiation between surface and interior structure.

13. Thickness of films.

14. Effect of low and high temperatures and high pressures, and the nature of recrystallization.

15. Uniformity of structure in different lots, in the same lot, in the same unit.

16. Differentiation fundamentally between same materials, with satisfactory and unsatisfactory properties for a given practical purpose.

2. *X-ray Diffraction Method*

Among the dozen or more possible experimental arrangements, the single method which most satisfactorily yields information of sixteen types enumerated above and which most successfully combines all the desirable attributes of an experimental tool is the pinhole method.

In Figure 3 is illustrated the essential experimental arrangement. The X-ray beam, defined by two pinholes in lead blocks or other suitable material, passes through a specimen placed over the outer pinhole, or is reflected from the surface of the specimen; the diffraction pattern is recorded on a photographic plate or film, usually flat and perpendicular to the beam, at a fixed distance from the specimen.

The method is one of extraordinary simplicity and flexibility. When the beam from any X-ray tube is used unfiltered there are many wave lengths. The pinhole method employing a polychromatic beam is simply the classical Laue method, useful primarily with single crystals as demonstrated for the single grain of iron in Figure 2. When, however, the beam of X-rays is filtered (for example, by means of a screen of zirconium oxide for molybdenum rays) so as to absorb all but a sensibly monochromatic ray, the method may be termed

monochromatic pinhole. It yields simpler patterns for single crystals and is applicable to powders, aggregates, fibers, and amorphous substances. There are many modifications: surface reflection; back reflection

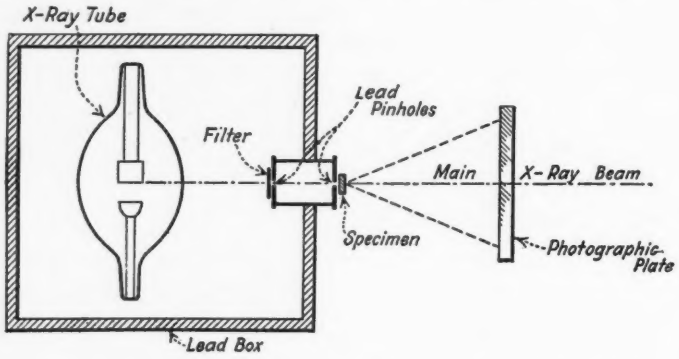


Fig. 3. Diagrammatic sketch of apparatus used to obtain pinhole X-ray diffraction patterns.

from very large specimens; cylindrical films co-axial with the specimen at the center, or co-axial with the beam; rotating specimen or pinhole, etc.

For economy of time and expense, in research and routine examination of commercial materials it is obviously of great value to be able to make several exposures simultaneously with one X-ray tube. The first multiple diffraction apparatus, combining the various modifications of the pinhole method and the Hull method, is shown in Figure 4. The apparatus is fully described in a recent paper; commercial equipment of similar design is now on the market. The apparatus is versatile in that several diffraction methods may be employed simultaneously and in that pinholes and slits are made removable, or readjustable to the target of the X-ray tube with its long axis vertical, and interchangeable. Such an apparatus may be operated continuously day and night and thus make possible accumulations of a mass of data in a comparatively short time. When slits are used to define the beam, and the specimen of a powder or aggregate is placed at the center of a circle on whose circumference (quadrant or semi-circle) a narrow film is bent, another type of result is obtained especially suitable for the determination of crystallographic system and unit dimensions. This method was devised by Hull and is so named.

3. *Typical Patterns*

(*a*) A single crystal produces a symmetrical array of spots lying on ellipses (Fig. 2), entirely characteristic of the particular architecture and constitution of such a crystal. Hence, the pattern may be analyzed and the ultimate construction of the crystal deduced. The crystal may be either stationary or revolved, the latter method now being in favor because of the more complete analysis possible.

(*b*) A powder or fine-grained aggregate compound of small crystal grains in random orientation produces a diffraction pattern of concentric uniformly intense rings, whose number, spacings, and relative intensities are characteristic for the material. In the so-called Hull powder method, straight spectral lines are obtained on a narrow film. If the crystal grains are larger than 10^{-3} cm., the

diffraction lines are spotted and dashed, while if the particle size is smaller than 10^{-6} cm., the lines become broader in proportion as the size decreases, so that a measurement of line breadth permits a determination of particle size in the range of colloidal dimensions.

(*c*) If a material is built up of small crystal grains which are all oriented in a definite way with respect to a common direction, the pattern characteristic of all fibrous materials is obtained. Figure 5-*a* shows the diffraction pattern for almost perfect asbestos fiber, the hyperbolas being this criterion. A great many natural materials are fibrous to a greater or less degree, including minerals, cellulose of all sources, silk (Fig. 5-*c*), cobwebs, etc. Fibering is artificially produced by rolling or drawing metals (Fig. 5-*b*, aluminum wire), in manufacturing rayon and in stretching rubber and other materials. Fiber structures are of the greatest practical importance in all fields; the patterns are more easily analyzed than other types, since at least one fundamental unit spacing or identity period is deduced without any assumptions. It is obvious that a fiber is characterized by strongly directional properties.

(*d*) Conditions of internal strain or distortion, so tremendously important in the practical behavior of all materials, is evidenced in diffraction patterns of the pinhole type by long radial streaks or asterism striations. A bent single crystal produces a pattern in which the single spots have been elongated into streaks, as though a plane reflecting mirror had been converted into a cylindrical one. Internal strain is particularly serious in chilled cast metals, and the X-ray pattern is the sole criterion that the undesirable condition has been removed by a satisfactory annealing process.

(*e*) Finally, we may ask what type of pattern should be expected from the so-called amorphous substances—liquids, gels,

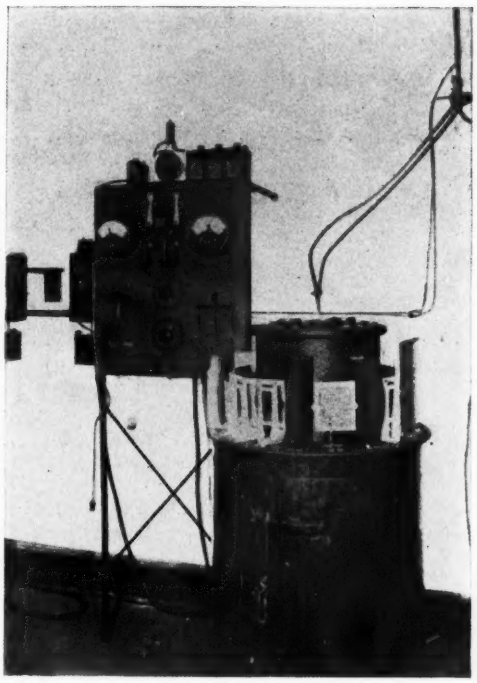


Fig. 4. Multiple diffraction apparatus with which eighteen photographs may be taken simultaneously with one X-ray tube.

etc.—which have absolutely no outward indication of any ultimate interior regularity in the sense that the outward geometric regularity of crystals must be an indication of interior regularity of construction. For all such substances the pinhole diffraction pattern is one or more broad rings instead of the general fogging of a photographic plate which absolute irregularity in structure would produce. It has just been discovered that the spacing, the intensity, the number, and the sharpness of these rings are extremely sensitive to any change in the substance and that they are as *highly characteristic* as any crystal pattern. The ring diameters are actually a measure of the *distance* of *nearest* approach of the ultimate molecules in thermal agitation as they lie side by side or end to end. From the standpoint of biological materials, this is the most

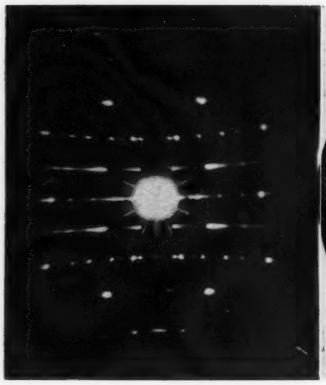


Fig. 5-A. Typical monochromatic pinhole pattern for perfect fiber (asbestos), as shown by hyperbolas.

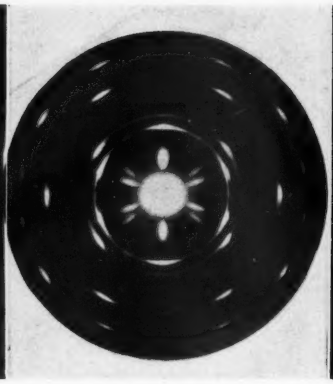


Fig. 5-B. Pattern for cold-drawn aluminum wire, showing high degree of fibering.

Fig. 5-C. Fiber diagram of natural silk.

important of all types of structural patterns. The fact that the simple patterns yield information so fundamental and far-reaching for materials which would seem hopeless for X-ray study is now the newest and most promising of all the contributions which chemical and industrial applications may bring back to biology and medicine.

V. SOME RESULTS IN THE STUDY OF FINE STRUCTURE OF MATERIALS

A. Elements and Inorganic Materials

1. The ultimate crystalline structures of about 60 of the 89 chemical elements now known have been uniquely determined. Most of the pure metals crystallize in the face-centered cubic, body-centered cubic, or hexagonal close-backed systems. This has made possible an interpretation in fundamental terms of the physical properties of metals, such as ductility, and the deduction of the sizes of atoms.

2. More than 500 pure inorganic chemical compounds in crystalline form have been analyzed for crystalline structure, ranging in complexity from rocksalt to complex silicate minerals, and to such compounds as triammonium heptafluohafniate. This vast fund of experimental information has made possible a knowledge of the solid state for the first time, and also a number of important generalizations and classifications as to Nature's methods of building atoms and molecules into crystals.

3. Polymorphic forms of elements or compounds have been discovered (chromium, cobalt), verified (α, β, γ, δ iron), or disproved (zinc, etc.).

4. Complete alloy systems have been analyzed and the ranges and mechanism of solid solution, intermetallic compounds formation, etc., discovered for brass, bronzes, steel (iron—carbon) and many other systems, supplementing and in many cases displacing thermal phase-rule analysis. New alloys with certain desired properties have been predicted and produced upon the basis of X-ray information. Hardness has been explained upon the basis of distortion and keying against slip of lattice planes.

5. Of greatest possible metallurgical importance have been the remarkable analyses of the effects of fabrication of metals, producing fibrous or strained structures. The consequences are: a knowledge of the mechanism of deformation, the effects of small amounts of impurities, the mechanism

and conditions for recrystallization, the heat treatment necessary to relieve strain and directional properties, correlation of physical properties (tensile strength, ability to form, magnetic properties, change in constitution with time, etc.) with ultimate structure, and the removal of the metal industry from empirical processes to scientific technic, assuring a satisfactory product. Some of the studies of commercial importance in the writer's laboratory are as follows:

(*a*) Cast steel: failure as result of strain and suitable heat treatment.

(*b*) Forming steel: prediction of performance and specifications for given grade upon the basis of the X-ray pattern.

(*c*) Rail steel: cause of transverse fissures.

(*d*) Electric steel: structure as a function of magnetic hysteresis loss, the larger and *freer* from strain the grains, the smaller the loss.

(*e*) Welds: structure of various zones, comparison of various methods of welding, and the superiority of the hydrogen atmosphere type.

(*f*) Steel wire: cause of die cutting.

(*g*) Silver plate: effect upon recrystallization of traces of iron (detrimental) and copper (helpful).

(*h*) Brass: season cracking.

(*i*) Copper: corrosive and non-corrosive in ammonia liquors.

(*j*) Electrodeposited metals: fibrous structure, grain size, constitution, etc., as functions of deposition conditions.

(*k*) Duralumin and other light alloys: constitution, aging and changes in structure with stress, as in aircraft frames.

6. A larger number of inorganic substances of industrial importance have been subjected to X-ray diffraction analysis in order to solve problems, as enumerated above, in the various types of information. Some of these are as follows:

(*a*) Lime: structure, impurities, grain size, as they affect plasticity; hence the determination of proper conditions of burning to yield most plastic product.

(*b*) Plaster of Paris: cause of decreasing strength upon successive recalcinations and rehydrations, found in growing particle size, prevented by adding ¼ per cent aluminium oxide.

(*c*) Portland cement: constitution of all constituents and combinations.

(*d*) Protective coatings on iron: constitution of oxide layers and their thicknesses.

(*e*) Porcelain: relationship between silicates in constitution (mullite and sillimanite with different constitutions give same crystal pattern); internal strain in spark plug porcelain.

(*f*) Asbestos: identification of each of several varieties, and effects of heat and acid treatment; specification by X-ray pattern for best variety for catalyst base, heat insulator, brake band, etc.

(*g*) Pigments: identification.

(*h*) Quartz: modifications.

B. Organic Compounds

The application of X-ray methods to the compounds of carbon is the most recent and amazingly full of possibilities, particularly in the analyses of the vast number of complex organic substances of which living organisms are constructed. The studies have been along the lines of unique analyses of single crystals, the interpretation of stereoisomerism, molecular symmetry, optical activity, the orientation, length, and polymorphic forms of long chain compounds in thin films, and the analyses of natural materials such as waxes, greases, butters, etc.

Some of the studies of chemical and industrial importance are as follows:

1. The outstanding result of X-ray studies of long chain compounds is that the lengths of molecules may be measured, inasmuch as in thin films the molecules ar-

range themselves parallel to each other in successive diffraction layers, to which the molecules are more or less perpendicular. Complications arise from the fact that some pure substances may show as many as three different spacings. In general, however, the long diffracting spacings in an homologous series of paraffin hydrocarbons, acids, alcohols, soaps, esters, ketones, glycerides, etc., are linearly related to the number of carbon atoms. The experimenter may thus analyze any unknown mixture of long carbon chains, or determine a molecular weight by reference to the linear graph.

2. The writer has studied paraffin waxes and observed that these mixtures of as many as eighteen hydrocarbons give diffraction lines for only one hydrocarbon. The spacings corresponding to chain lengths vary, depending upon the rate of cooling, and impurities for any given commercial wax. Such properties as transparency are related to these spacings.

3. The mechanism of lubrication is deduced from the lining-up of long soap and glyceride molecules by the bearing.

4. The identification of dyes and dye intermediates.

5. The soaps and glycerides in drying oils have been studied.

6. Another interesting outgrowth of organic crystal analyses is the application of some of the long chain compounds with large spacings as crystal gratings for the measurement of very long wave lengths. In this way Dauvillier, in France, was able to bridge the spectral gap from 20 to 136 A.U., using lead melissate (spacing 87.5 A.U.) as grating.

7. Many problems in the structural theory of organic compounds are being solved from crystal data, particularly as regards the explanation of optical activity from actual spiral arrangement, the space requirements for substituent groups, and the symmetry of molecules.

C. Colloidal and Amorphous Materials

1. *Catalysts:* Clark, in continuing work on particle size of metal catalysts as related to the activity, finds from photometric measurements of line breadths that there is a definite relationship between decreasing particle size to an optimum size, with increasing activity. These investigations of catalysts are being continued in order to discover the effect of every possible variable. The earlier work on nickel catalysts has inspired the new and excellent X-ray studies of catalysts by Levi, in Italy.

2. *Practical Studies of Colloidal Particle Size:* The above type of investigation can be applied with great value to the study of paints, pigments, and enamels. Clark, in the paper just referred to, reports measurements on a series of samples of stannic oxide used in enamels in which the particle size varied from 10^{-3} to 5×10^{-7} cm., as determined from the widths of the diffraction lines. Obviously, covering and obscuring power are intimately related to particle size. Clark and Brugmann measured the particle size of case-hardened steel (martensite and troostite) to be nearly 10^{-7} cm.

3. *Carbon Black:* A continuous transition by heat treatment between an active charcoal with an X-ray pattern, indicating as nearly the amorphous state as possible (one very ill-defined ring), and graphite (sharp, many-line crystal spectrum) has been observed by the writer. He found that the change in X-ray pattern of the active carbon lags behind the change in physical and chemical properties to those of graphite. This is evidence of a paracrystalline state in which crystalline layers are still too few and distorted to produce definite interference maxima. These studies are promising for the discovery of the desired properties of carbon in rubber.

4. *Rubber and Allied Substances:* The first published account of the fact that rubber, when stretched, produces a crystalline

fiber diffraction pattern was by Katz. This fact had been observed by Clark (Fig. 6); the essential phenomena described by Katz, though not the details, have been confirmed by him and by Hauser and Mark, in Germany. Clark and Hauser and Mark agree that a unit cell containing $(C_5H_8)_8$ is indicated from X-ray data, and that, upon stretching, a lower polymer phase is forced out of a higher polymerized phase, which is thereupon oriented for diffraction. That this is due to the rubber hydrocarbon is demonstrated by new work by Clark on very pure soluble rubber. The most interesting feature at present is that no sample of synthetic rubber has been found to produce this sharply fiber diagram. It is possible that this is the criterion of a successful artificial reproduction of rubber. Another recent development is the X-ray study of "racked" rubber, stretched 10,000 per cent. Whereas, rubber stretched once begins to show a fiber pattern at 75 per cent elongation, "racked" rubber when released with a permanent set of 1,000 per cent, produces only the amorphous pattern. Clark has reported the only results and calculations on balata and gutta percha, which differ from each other and from rubber; both contain crystalline matter when unstretched, while rubber ordinarily does not. Gelatin and glue in stretched condition also show an incipient crystal-like arrangement. The polymerization of shellac, upon heating, has been followed by X-ray photographs.

5. *Liquids and Gels:* Great interest has been aroused recently in the interpretation of "amorphous" patterns consisting of two or three diffuse diffraction rings. It is now definitely established that these are indicative of the distance of nearest approach of molecules or aggregates acting as units. Steward and Morrow propose the term "cybotaxis" for this state, and they propose to apply the conception to osmosis and other phenomena. The present results on liquid primary normal alcohols which show two spacings, one corresponding to chain length and one (constant for all) to cross-section, are in every way analogous to results with the solid state. Clark has discovered that polymerization, oxidation, photochemical action, and solvent swelling of gels in rubber, nitro-cellulose, linseed oil, and tung (china wood) oil (liquid and dried films) are indicated in a remarkable way by these simple patterns. In the last two cases, over-aging is accompanied by actual crystalliza-

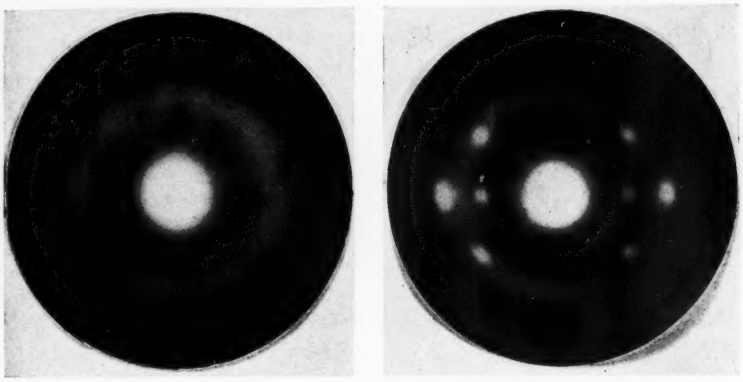


Fig. 6. Patterns (from left to right) for unstretched (amorphous) and stretched (crystal-fiber) rubber.

tion. Extremely interesting and valuable results on pure liquids are now being accumulated. In these simple non-crystalline patterns it is possible to distinguish between ortho-, meta-, and para-isomers in organic compounds, between structural isomers and between types of compounds (for example, between aniline and nitrobenzene). The inner edge of the diffraction rings for liquid mercury is very sharp, entirely in keeping with the very small compressibility of the liquid and with the conception of a distance of nearest approach of molecules.

6. *Cellulose and Silk:* Clark, Freudenthal, and Kulp have subjected a long series of natural cellulose fibers and all types of rayon to X-ray investigation and have found them all to be crystalline except diacetate rayon. For natural or regenerated cellulose the same lattice is found by Herzog, Katz, Sponsler, and Dore, and others are indicated (rhombic $(C_6H_{10}O_5)_4$), but the degree of fibering varies widely from random in a viscose film to nearly perfect in ramie and flax. Tension on the fiber in rayon production has large effects upon the fibering, as disclosed by X-ray diffraction and also upon important practical properties. In two extremes of the same rayon, one in which the fiber structure is strong, indicating regular arrangement of the crystal units with respect to the fiber, and the other a nearly random arrangement, the latter specimen did not compare with the former in strength and durability. By way of comparison the sharply fibrous structure of the natural protein silk is shown in Figure 5-*c*. In every phase of the textile industry, from raw material to finished cloth, such as washing, swelling, drying, mercerization, dyeing, aging, etc., the X-ray diffraction method may be used to good advantage.

D. The Structure of Biological Materials

Upon the basis of the remarkable applications of the X-ray diffraction method to chemical and industrial materials, it follows that the study of the ultimate structure of biological materials should yield information not obtainable by any other method. Because this type of examination is so new, the results lie largely in the future, but some of these already recorded are as follows:

1. *Bone Structure:* The calcium phosphate which produces rigidity in bones is distinctly crystalline and yields a typical powder spectrum not yet completely analyzed, since the complex pattern of lines varies with age or pathological condition. Besides constitution, the grain size (which also varies with age, location in the bone, etc.) and distortion are easily ascertained. In a study now in progress in the writer's laboratory, the bones from normal and abnormally dwarfed carp inhabiting the rivers of Illinois, are clearly distinguished by their ultimate structures and by the unusual distortion in the latter instance. Much remains to be done in developing all the possibilities of bone structure.

2. *Other Calcareous Structures:* Many shells produced by living organisms have been analyzed. Most of these, such as coral, sponge, spines, and marine shells, have the structure of calcite, the rhombohedral form of calcium carbonate, and others, of aragonite, have the rhombic form. Ordinary hen eggs are distinguished by a pattern indicative of considerable distortion. Dental enamel has a multiple or cylindrical fiber crystalline structure. Pearls are crystalline and the pattern is so distinctive that the natural specimens are easily distinguished from those cultivated from a mother-of-pearl center.

3. *Gelatin, Collagen and Other Proteins:* It may be predicted that all substances which shorten when they are warmed in the stretched condition, such as gelatin, glue, muscle fibers, etc., will display X-ray phenomena similar to rubber. The writer

has found that pure ashless iso-electric gelatin, unstretched, produces a broad amorphous ring corresponding to a spacing of 4.2 A.U., and an outer sharp ring related to a crystal spacing of 2.8 A.U. For gelatin not at the iso-electric point the sharp ring does not appear. Katz and Gerngross have verified the above prediction for stretched gelatin, and Herzog and Gonell for collagen. For a pure iso-electric gelatin gel the former obtained a diagram which agrees with that independently observed by the writer. When stretched 50 per cent the sharp circle became merely two unconnected crescents in the stretching direction, showing the preferred orientation of the crystals originally present. At 100 per cent elongation, larger elliptical intensity maxima appeared on the film perpendicular to the stretching direction, one pair joined to the central direct beam spot and corresponding to a spacing of 10 A.U., and the other pair on the inner side of the broad amorphous ring corresponding to 5.5 A.U. Almost identical results were obtained with fibrous collagen (tendon of Achilles). Herzog and Gonell studied apparently unstretched collagen from six separate and widely varied sources, including three from connective tissue and three from cartilage. The diagrams for all except fish scales were cloudy, showing the presence of amorphous material with the crystalline. In some cases digestion with trypsin solution removed the amorphous material, leaving the crystalline. The crystal component of all the collagens gave exactly the same diagram. The elastin from the neck ligament of cattle thus appears identical with collagen. Perfectly definite interference bands indicate a tetragonal form, and the particle size, calculated from the line breadth, is 90 A.U. It is clear, however, that the mass per unit crystal cell of protein must be far smaller than that demanded by the usual formulas for gelatin, which may yield as many as 13 amino-acids. The X-ray information concerns a unit much smaller than the estimate of the colloid chemists on molecular size.

Tendons, treated 24 hours in cresol at 38°, show a marked change of the X-ray diagram and point to the presence of at least two substances in the collagen. When the strongly swelled tendons remain for some time in air the cresol evaporates, the swelling goes back, and the tendon becomes elastic but gives the same changed diagram. When washed 24 hours in benzene the original diagram is obtained. Leather as it is variously tanned has been studied, so that it is possible to distinguish the method of tanning from the diameters of the diffraction rings when compared with standard patterns. It is remarkable that silk, a natural protein, has so nearly perfect a fiber structure as compared with the other proteins. Even more perfect is the cobweb, the diagram of which indicates a constitution like that of silk. It is unfortunate that silk is not absorbed by the human system, for it would have long ago displaced catgut for surgical sutures because of its ideal fiber structure, productive of great strength.

4. *Chitin:* This substance, from various sources, contains the same crystalline substance, the differences lying in the arrangement and size of crystallites and in the content of amorphous material. The elementary substance contains 18 acetyl-glucosamine anhydride molecules of which 1, 2, 3, 6, or all contained in one crystallite may form a group.

5. *Muscle Fibers:* New studies just completed on frog muscles under tension verify the prediction that, upon stretching, the tendency should be towards lining up structural units as in rubber. However, gelatin and muscle fibers at the greatest possible elongation before breakage do not yield sharp interference spots, as in the case of rubber, but simply a change in the broad rings to indicate an orientation in one or

two but not in three dimensions. In this respect also all synthetic rubbers thus far produced are the same.

6. Some biologically important substances which appear to be crystalline in habit and doubly refractive, such as *hemoglobin and edistin*, do not yield crystal X-ray patterns, so that for some reason they are merely pseudo-crystalline. On the other hand, *albumin* has been crystallized by the Sorensen method and found to be truly crystalline, although the analysis of this is not yet complete.

7. *Fluids:* Finally, the vast field of body fluids and gel structures must be considered. The extreme sensitiveness of the liquid patterns to structure and constitution renders it possible to study in a fundamental sense tissues, gels and fluids, the mechanism of swelling, and the actual molecular or molecular aggregate dimensions. As an example may be cited blood in all its conditions, even to carbon monoxide and lead poisoning. These analyses should be made as readily as they have been for linseed oil under various conditions, resulting in great improvements in the manufacture of patent leather. In other words, here is a new type of research diagnosis in medical science, which penetrates unerringly to the fundamental unit of structure or constitution. By means of it we may begin to unravel the complexities of the single cell, the tissue, the whole organism, and to understand in definite ways the interrelationships, the proper and improper functions, the normal and abnormal structures, and even the effects of the direct action of the very radiation which we are turning to new account as a research tool.

ON A FORAMEN IN THE LOWER EXTREMITY OF THE HUMERUS

By I. SETH HIRSCH, M.D., D.M.R.E. (Cantab.), NEW YORK CITY

DURING flexion of the forearm the coronoid fossa of the humerus receives the coronoid process of the ulna. On the posterior surface above the trochlea is a deep triangular depression, the olecranon fossa, in which the summit of the olecranon is received in extension of the forearm. These two fossæ are separated from one another by a thin, more or less transparent lamina of bone, lined in the fresh state by the synovial membrane of the elbow joint.[1]

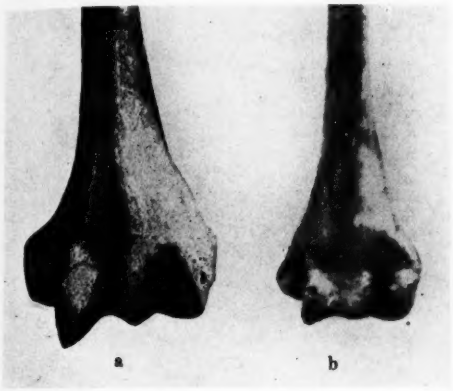


Fig. 1 (*a*) Humerus of the modern European. (*b*) Humerus of Senoi. Note the difference in the obliquity of the condyles; in the Senoi it is almost horizontal. In (*a*) the radial fossa is shallow and much less developed. In (*b*) the fossæ are of equal size.

The plate of bone separating the coronoid and the olecranon fossæ may be perforated. This opening is called the supratrochlear foramen.[2] It is a more or less oval or elliptical opening with a smooth margin and sloping edges with the long axis transverse, about 5 to 9 mm. wide and 3 to 4 mm. high. It is located above the epiphyseal line and is in the intra-articular part of the olecranon fossa below the line of reflection of the synovial membrane which crosses the middle of the fossa.

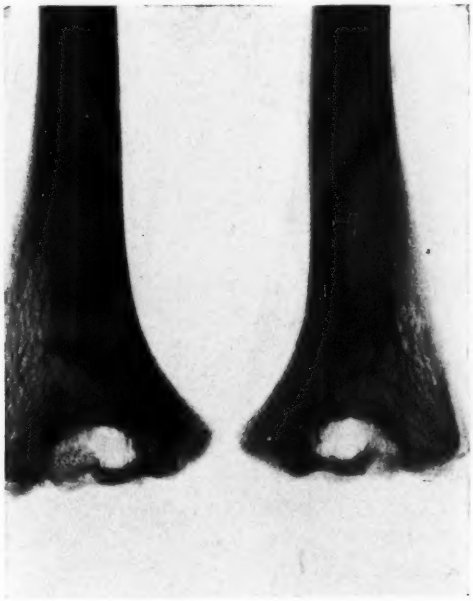


Fig. 2. Infant gorilla with intact septum.

When large, the hole is actually in an open state; when small, it may be covered

1The margins of the fossæ afford attachment to the anterior and posterior ligaments of this articulation. Under cover of the transverse fibers of the posterior ligament, which form a strong band bridging across the olecranon fossa, is a pouch of synovial membrane lining the fossa. Projecting into the upper part of the fossa is a large fat pad which is pressed into the fossa by the triceps.

2This name is not to be confused with the supracondyloid foramen formed above the median epicondyle, by a complete osseous or fibrous bridging of the supracondylar process. This foramen is present in many mammals and reptiles. The supracondylar process may be associated with the supratrochlear foramen as in Figure 14. This supracondylar process is fairly common in man, though the foramen is rarely found.

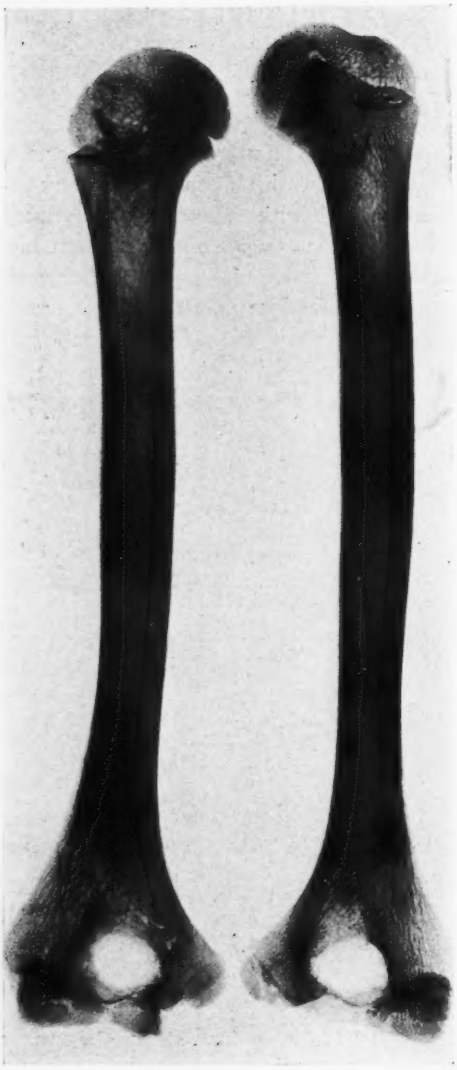


Fig. 3. Humerus of a young gorilla with a large supratrochlear foramen.

by a membrane. Even when the bony septum is intact, it may contain several small perforations.

The supratrochlear foramen is not present at birth. In young individuals the bony septum is relatively thick, as much as 4.4 mm. in the new-born. The septum is gradually absorbed during childhood, producing

Fig. 4. Humerus of an adult gorilla with intact septum. The perforating nutrient foramina are almost identical in position with those in the human bone (condyle shows a saw-cut).

the foramen, which has not been observed before the sixth year.

The supratrochlear foramen is found only in mammals, both in the lower and the higher orders. It is absent in swimming and flying forms and in terrestrial forms adapted to life in the water. It is inconstant in various species and its absence or presence cannot be taken as an index for the species, since there may be individual variations. But when specimens of several species of the same genus show it, its general occurrence in the species, if not in the genus, is a justified assumption. Among the marsupials it is found in the permeles; among the ungulates, in the wild pig, hyrax and others. Some of the beasts of prey—

Fig. 5. Two left humeri (old Egyptian), one with perforation and one with intact septum.

Fig. 6. Right humerus of old Egyptian, with perforation.

Fig. 7. Left humeri, with well-marked supratrochlear foramina (ancient Indians of Salt River Valley).

hyena, wolf, jackal, and various insect eaters—have this characteristic.

As in man, so in the lower animals, the humerus is imperforate in the embryonal stage. The perforation is frequently found in semi-apes and apes.

Darwin mentions this foramen in the human as being one of the characteristics that show man's close relationship to the lower forms. He states that it occurs, but not constantly, in various anthropoid and other apes, in the full-grown gorilla, orang and chimpanzee. In the gibbon no supratrochlear foramen is present in infancy.

Anthropologists have studied the fre-

Fig. 8. Right humeri, with well-marked supratrochlear foramina (ancient Indians of Salt River Valley).

quency of this foramen in various groups of people. The percentage of its occurrence varies greatly. Martin claims that this characteristic is relatively rare in late Europeans, but is commonly present in the Neolithic and the prehistoric types, and the statistical data which he has tabulated seem to indicate the greater frequency of the foramen in ancient primitive people. It has been found in the humeri of skeletons from the caverns of Montmaigre, the sepulcher of Chelles, and the excavations of Chaumont wherein were found the bones of men of the Stone Age. The highest frequency (58 per cent) appears to be in the Veddas (an ancient primitive people of the jungle of Ceylon), whose humeri, even when not perforated, show a very thin septum, according to the excellent observations of the brothers Sarasin, in the primitive Arkansas Indians, and in the Egyptian humeri taken from old Libyan graves.

The lowest percentage is given by the Parisians of the Middle Ages and white Americans. Hultkrantz found the foramen in 4.7 per cent of 150 males' arms and 14.8 per cent of 54 females' arms of Swedes.

Fig. 9. Right arm of P. McC., male, aged 9. Supratrochlear foramen and old oblique fracture, external portion diaphysis through foramen. Recovery, with a loss of ten degrees carrying angle.

The foramen was present in 15.4 per cent of 52 humeri from the Stone Age, and not a single specimen was found among 59 humeri of Lapps.

From the data collected it is evident that the characteristic is not confined to any one race, and that it has greater frequency in the female and on the left side.

The question naturally arises, Of what significance is the foramen? Why is it disappearing from the humeri of modern man? Why is it more frequent in the female and on the left side? If it could be proven that

Fig. 10 D. B., male, aged 10. Supratrochlear foramen, double, the left side larger than the right. Evidence of old fracture of external portion of diaphysis. Recovery, with a loss of ten degrees carrying angle.

Fig. 11. W. H., male, aged 12. Supratrochlear foramen, double.

there is any relationship between the presence of the foramen and an increase in the flexion and extension amplitude at the elbow joint, its significance would be apparent. It then would mean that there has been an adaptation to functional needs and that, on the whole, modern man has lost to a certain degree the range of these particular motions possessed by his prehistoric ancestors, in whom this foramen is a more or less constant finding; and that this character is in recession and will eventually disappear. The little motion modern man has lost by this change has, of course, been more than compensated for by the general greater latitude of motion in other directions, made possible by greater obliquity of the condylar portion than exists in primitive man and animals.[3]

It is true that the foramen appears to be associated with an increase in the amplitude of the extension movements in the joint. This is only slight in the fully formed joint, for the range of the extension movements of the elbow is undoubtedly limited by the

3In the evolution of man the condylar portion of the lower end of the humerus has undergone considerable modification. If the position of the elbow axis is studied by measuring the condylo-diaphyseal angle, formed by a tangent to the trochlea and the axis of the diaphysis, a marked difference between the old and the recent man will be found. (Fig. 1.)

In the Neanderthal man, the trochlea is practically horizontal, while in modern man its axis is oblique. With the change in the axis there have been structural changes in the trochlea, particularly in the development of the coronoid and the radial fossæ. In the Senoi both fossæ are practically alike, and the bony ridge that separates them runs directly downward in the axis of the diaphysis. In the modern Europeans the ridge deviates externally. Because of this, the coronoid fossa has come to be practically in the center of the bone, just above the trochlea, while the radial fossa is lateral to the central axis of the diaphysis.

Fig. 12. F. K., aged 16. Left supratrochlear foramen. Note the two tubercles, one on the anterior external aspect and one on the posterior internal aspect of the foramen.

ligamentous and muscular structures. In one case of bilateral foramen (Fig. 11), hyper-extension was marked.

It has been thought that this foramen might be the result of trauma incidental to peculiar occupations, wherein increased and continuous extension movements took place. The presence of this perforation (as disclosed by the X-ray examination) in living individuals of different nationalities, both children and adults, who have not indulged in any extraordinary muscular movements, is sufficient to demolish any hypothesis based on the theory of trauma.

At about the seventh year the ossification of the trochlear epiphysis begins and the growth of this part of the bone proceeds rapidly. It is at this time that the bony plate between the coronoid and olecranon fossæ becomes cribiform, lamellar atrophy begins, the intralamellar spaces enlarge, and absorption of the central part of the septum finally takes place.

The process of absorption is undoubtedly associated with and influenced by modification of the blood supply. The nutrient vessels, which are chiefly supplied from the inferior profunda, enter this portion of the bone by nutrient foramina, which are intra-articular. They are visible in radiographic studies in the upper contour of the foramen, one on either side.

It may be that the formation of the foramen is a phenomenon secondary to incomplete and insufficient vascularization, which, as evolutionary development proceeds, becomes corrected and compensated for. The greater frequency in the female and on the left side may be explained on the hypothesis that the female humerus and the left humerus are, as a rule, somewhat less developed than the right.

It is thus apparent that this anatomic variation is of interest from the standpoint of man's philogenetic relationship. It is one of the many markings which permits the anthropologist to study the moulding effect of the countless ages of struggle on the part of man to attain his present anatomic form.

The anatomist, zoölogist, and anthropologist all have shown an interest in this foramen, and it is surprising that the roentgenologist, whose opportunities for studying living material permit him to contribute valuable data, has concerned himself so little with the subject. The foramen has not only a theoretical but also a practical bearing because of the frequency of fractures in this portion of the bone. It might seem that, in the presence of this foramen, greater difficulty might be experienced in getting perfect anatomic and functional restitution.

An increase in radiographic illumination of this area is seen under normal conditions because of the comparative thinness of this portion of the bone, but all lamellar mark-

ings must be absent and the foramen must be rimmed with a thin edge of compacta, for the correct diagnosis. The foramen is usually oval, except when deformed as a result of fracture (Cases 1 and 2). The long axis is parallel with a line between the epicondyles. The oval contour is normally modified by the presence of small spurs, one in the upper and inner, and one in the lower and outer contour of the foramen. The roentgen-ray studies of the living would indicate that it is frequently double and always larger on the left side.

The frequency of a fracture through the lower one-quarter to one-half inch of the diaphysis in children under six may be explained by the anatomic structure of this part of the bone. Epiphyseal separation occurs only rarely. Though the very elastic nature of the epiphysis plays a part in its preservation, it is the weakness of this portion of the bone, because of the thin septum or foramen between olecranon and coronoid fossæ, which predisposes it to fracture.

In supracondylar fracture, when the fracture line extends through the region of the foramen the indented edge of the foramen may be made out in the lower fragment.

Above the olecranon there is sometimes present a detached rounded ossicle, the sesamum cubiti (Pfitzner). Figures 15 and 16 show this rather large rounded nucleus of

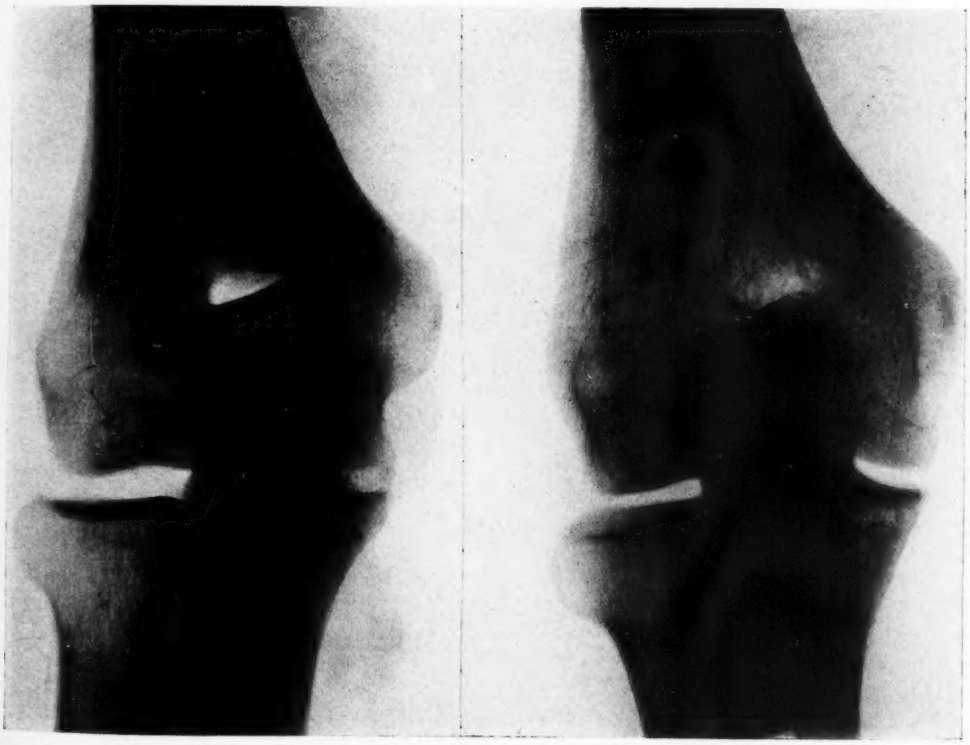


Fig. 13. A. S., male, aged 22. Left supratrochlear foramen. On the right side the septum is thin but not perforated.

Fig. 14. E. C., female, aged 23. Left supratrochlear foramen. Note the supracondyloid process, a sharp spur formation above the median epicondyle.

bone. It appears to lie within the foramen, the edges of which are considerably thickened. It is not to be mistaken for the center or centers (two or three) of ossification of the epiphysis showing through the supratrochlear foramen. These appear from the tenth to the thirteenth year and fuse from the sixteenth to the twentieth year.

As a rule, this ossicle is seen well behind the humerus, but because of the foramen it may come to lie within it, being pressed into the position by the triceps. If there are arthritic changes in the elbow, these sesamoids partake of the productive changes and may become very large. If the olecranon process is the analogue of the patella, this sesamoid may correspond to the supratrochlear ossicle.

SUMMARY

1. The supratrochlear foramen should be looked for in the roentgenogram, and noted, not only because of its clinical but also because of its anthropological interest.

2. It is not found before the age of six years and is usually bilateral.

3. It is more common in the female and is usually more characteristic and larger on the left side.

4. It is an anatomical variation and must not be misinterpreted in injuries to the elbow.

5. An increase in hyper-extension was

Fig. 15. P. K., male, aged 32. Large supratrochlear foramen containing ossicle. Productive arthritic changes.

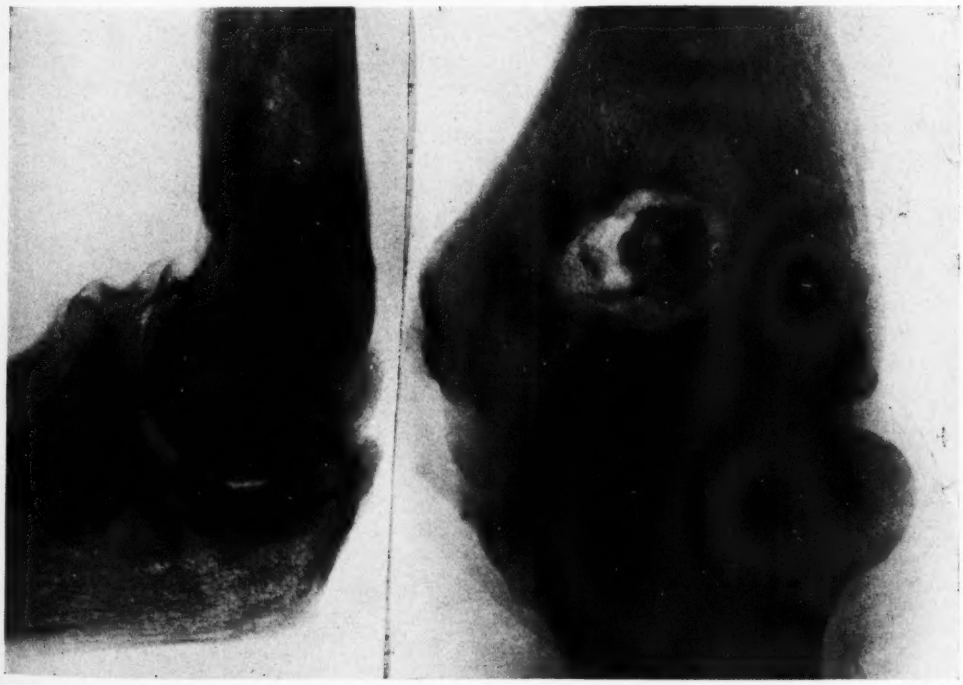


Fig. 16. J. J., male, aged 30. Large supratrochlear foramen containing ossicle. Productive arthritic changes.

found in association with a bilateral supratrochlear foramen in a child.

6. A spherical ossicle is described, probably the sesamum cubiti of Pfitzner, which has been pressed into the foramen by the overlying structures.

I desire to acknowledge the courtesy of Professor William K. Gregory, American Museum of Natural History of New York City, in permitting me to examine and radiograph the various specimens of humeri preserved in the museum.

Name	Sex	Age	Weight	Right Arm	Left Arm	Figure
P. McC.	M	9	.....	Regular	No film	9
D. B.	M	10	75	Regular	Irregular	10
W. H.	M	12	102	Regular	Regular	11
F. K.	?	16	.....	No film	Regular	12
A. S.	M	22	175	Absent	Regular	13
E. C.	F	23	.....	No film	Regular	14
P. K.	M	32	145	Regular	No film	15
J. J.	M	30	.....	Regular	No film	16

FURTHER STUDIES OF THE EFFECT OF GRADED DOSES OF X-RAYS ON ANIMALS FED ON VARIOUS DIETARIES, WITH A NOTE ON THE EFFECT OF DIETARY IN THE TREATMENT OF PATIENTS WITH X-RAYS[1]

By MONTROSE T. BURROWS, M.D., and LOUIS H. JORSTAD, M.D., from the Department of Research, and EDWIN C. ERNST, M.D., from the Department of Radiology, of The Barnard Free Skin and Cancer Hospital, St. Louis, Missouri

In previous papers (1) (2) (3) we have described studies of the effect of small repeated and larger repeated doses of X-rays on rats. In these earlier experiments we studied the effect of doses ranging between 10 milliampere minutes[2] (13 *e*-units) and 50 milliampere minutes (68 *e*-units) given twice a week to rats fed on a balanced dietary and other rats fed on diets deficient in Vitamins A and B, respectively. In these experiments we showed that doses of 13 *e*-units given twice a week protect for a considerable time rats fed on a diet deficient in Vitamin B, while they have little effect on rats fed on a diet deficient in Vitamin A. Larger doses of 34 and 68 *e*-units, respectively, given twice a week, protect for a considerable time not only rats fed on a diet deficient in Vitamin B, but also those fed on a diet deficient in Vitamin A.

Previous observations on X-rays have shown that they may cause changes in the ionization of atoms; such changes may cause either synthesis in one case or a breakdown of molecules in another. How they affect the organism in terms of these facts has not been determined. Cellular activity, as we have observed it, is the result of the primary formation of a stimulating substance or substances by the cell. This substance or group of substances is actively diffusible and soluble in water. It acts on the cell differently, according to its concentration. This substance or group of substances has been called the archusia (S). In low concentrations (S^1) it has no effect, in medium concentrations (S^2) it causes the cell to liberate a lipoid substance or substances, the ergusia. In high concentrations (S^3) it causes an active digestion of proteins and fat about the cell, the cell to absorb products—including water—from the outer medium, grow and divide by mitosis. In still higher concentrations (S^4) it leads to the destruction of the cell, with the liberation of a soap or soaps, which decreases the surface tension of water and leads to an active growth of other cells. While this destruction of the cells resembles autolysis from the lack of oxygen, it is evidently not the same because toxic substances are liberated in the autolysis of cells (4) (5) (6).

In the normal organism the ergusia is utilized for function, the building of extracellular substances, for the migration of the fixed tissue cells, and growth. It is evidently one of the most important constituents of cellular protoplasm. It is not formed by the cells in quantities ample for life as it exists in the organism. This deficiency is supplied to the body from without by other cells in nature in the form of Vitamin A (7). Large quantities are liberated by the cells only as they suffer destruction, such as is noted when they are digested in the presence of an excess of the archusia (S).

While body cells are able to form the archusia (S) they cannot form and retain ample of this substance for life activities except when they are crowded together in nar-

[1]Read before the Radiological Society of North America, at the Twelfth Annual Meeting, at Milwaukee, Dec. 2, 1926.
[2]Technic: 215 K.V., filtration ½ mm. Cu., 80 c.m. focal skin distance, 48.2 per cent water phantom depth dose.

row stagnant confines and are freed from the excess of the ergusia. The ergusia in large quantities as it exists in the body acts as an inhibitor for protoplasmic changes. It is a product of the growth reaction and acts to inhibit normal reactions in protoplasm as any product of any reaction inhibits the reaction when present in excess. The deficiency of the archusia, as that of the ergusia, is supplied also from without. It is supplied in the form of Vitamin B (8).

It was through the knowledge of these facts that it became of interest to test the effect of X-rays on animals fed on diets deficient in Vitamins A and B, respectively. It is known that X-rays may induce cancer. Our previous study of cancer has indicated that the normal life of the animal depends upon a proper balance of Vitamins A and B, or the ergusia and archusia about its cells. The difference between the normal cells of higher animals and those of lower unicellular forms is the high content of ergusia in the former. Cancer results when this excess of the ergusia is removed from about the cells and they become crowded into narrow stagnant confines in the organism. The body cells then become reduced to a unicellular existence. It had become of interest to study how X-rays affect these changes. We have shown that drops of coal tar produce cancer through removing the ergusia from the tissues and cells about them and drawing the cells together away from their intercellular substances and crowding them about their peripheries (9) (4). It has also been shown that any actively growing tissues placed in the organism may remove this excess of the ergusia from the host tissue and induce cancer in these host tissues (10). Previous studies of ultra-violet light have shown that this light acts to liberate Vitamin A from animal and vegetable fats (11) (12). Our studies have shown no direct difference between the action of ultra-violet light and that of X-rays on animals as far as protecting them against a Vitamin A deficiency (2). It seemed possible, therefore, to assume that X-ray may induce cancer in areas of the body merely through mobilizing or separating the ergusia, or Vitamin A, from the cells and tissues in the organism. This freed ergusia will then be removed and utilized by other tissues in the organism. In proof of this conception it has been found that animals may be protected against a Vitamin A deficiency for a time by treating with moderately larger doses of these rays than those found ample to protect alone the animal for a time against a Vitamin B deficiency (3). X-rays act apparently, therefore, to produce changes in local areas of the tissues absorbing them, which are the same as those produced by removing the ergusia, or the Vitamin A fraction, from these tissues. The animal as a whole is affected differently, however, in that the ergusia is removed and dissolved in the coal tar, while the X-rays loosened it from its combinations in the cells and tissues. It is removed then and utilized by other tissues and cells in the organism.

The question that next confronted us was, How do X-rays affect these changes, and how can they be prevented or accelerated in the organism? Many authors have noted that these rays in small doses cause stimulation rather than destruction. In this regard these rays act as many toxic substances act. Whether one is to interpret this effect of small doses of X-rays or any toxic substance as stimulation has been subjected to much discussion.

In our previous experiments on the activity of cells in the tissue culture it has been shown these activities are dependent wholly on the immediate concentration of the archusia (S) about the cells. As noted above, while low concentrations of the archusia induce migration and growth, larger amounts cause a complete destruction of the cell. It was possible, therefore, as we have

noted in a previous paper (3), that X-rays may act only to induce the formation of the archusia and that the archusia in turn acts to liberate the ergusia, or Vitamin A, as it causes the cells to disintegrate. It had been noted that cells disintegrating in the presence of a high concentration (S^2 and S^4) of the archusia liberate Vitamin A.

While this explanation is interesting, it does not make clear the action of these rays on simple vegetable and animal fats. It seemed evident that there might be another interpretation of this phenomenon: these rays may act to produce general molecular disintegration in the cell. We have no evidence to show that the archusia is formed otherwise than through the disintegration of complex compounds either in the cell or its immediate environment, as the ergusia is the result of protoplasmic disintegration. The disintegrations leading to the liberation of these substances proceed more or less continuously in normally active cells. They are the result of the molecular changes from which the energy for life is derived. One might expect that if X-rays or any other toxic substances act only to cause disintegrations in protoplasm, they would act in small doses to accelerate those disintegrations already taking place in the cell, while larger doses would cause a general breakdown of the cell. The effect of small doses would be an increase in the archusia (S), slightly larger doses would lead to an increase in the ergusia, while still larger doses would cause a general breakdown of the cell.

In our previous experiments (2) repeated doses of X-rays have led always to an early death of the animal. In only one case where animals were given 4 doses of 150 milliampere minutes at wide intervals have a few of the animals on a minus B diet survived for a long time, or practically a normal life. No dosage has been found so far by which animals fed on a minus A diet may survive for a very long time. In fact, most of the animals fed on a minus B diet succumb after a short interval.

The picture in most of our cases has been, therefore, that of molecular disintegration rather than any evidence of primary stimulation. In following up these experiments it has become of interest, therefore, to study the effect of larger doses.

THE EFFECT OF LARGER REPEATED DOSES OF X-RAYS

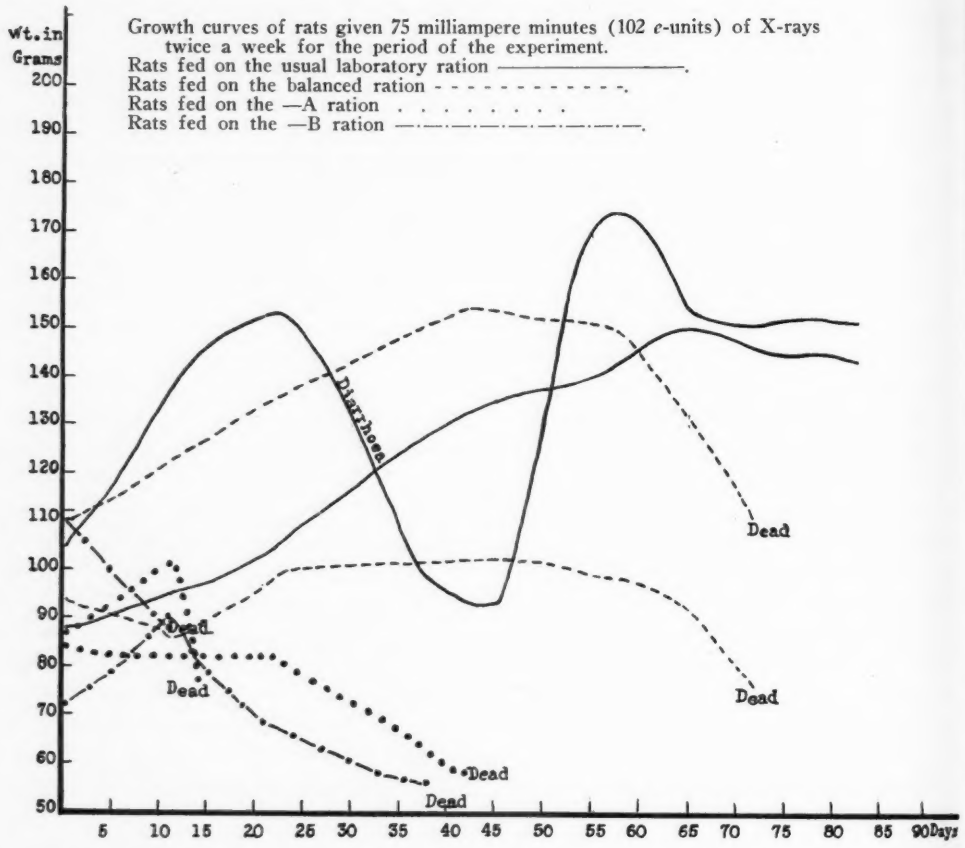
In the new experiments reported in this paper we have studied the effect of 75 milliampere minutes (102 *e*-units) and 100 milliampere minutes (136 *e*-units) on rats fed on diets deficient in Vitamin B and Vitamin A, respectively, a diet balanced in these vitamins, and the normal laboratory diet of stock animals.

As noted in the accompanying Curves 1 and 2, rats fed on diets deficient in Vitamins A and B, respectively, suffered an immediate drop in their growth curves and an early death as the result of these larger doses. Those fed on a diet balanced in these vitamins also suffered an early death.

In the Curves 1 and 2 we have charted only those rats which represent the extremes of the effect of the rays. As must be noted here, most of the rats fed on the minus B and minus A diets succumbed after a very short interval. There was no evidence of growth stimulation at any time. The whole picture was that of the effect of a toxic substance acting on them.

To give further proof for this general deduction as well as to reduce it to terms for practical application it became of interest to us in these same experiments not only to study the effect of these rays on animals fed on deficient diets, but also those fed on diets containing all the substances necessary for the proper life of these animals.

If X-rays act only to increase the archusia (S), or Vitamin B, and this, in turn, leads



Curve 1. The effect of repeated doses of X-rays (102 *e*-units) on rats fed on various dietaries.

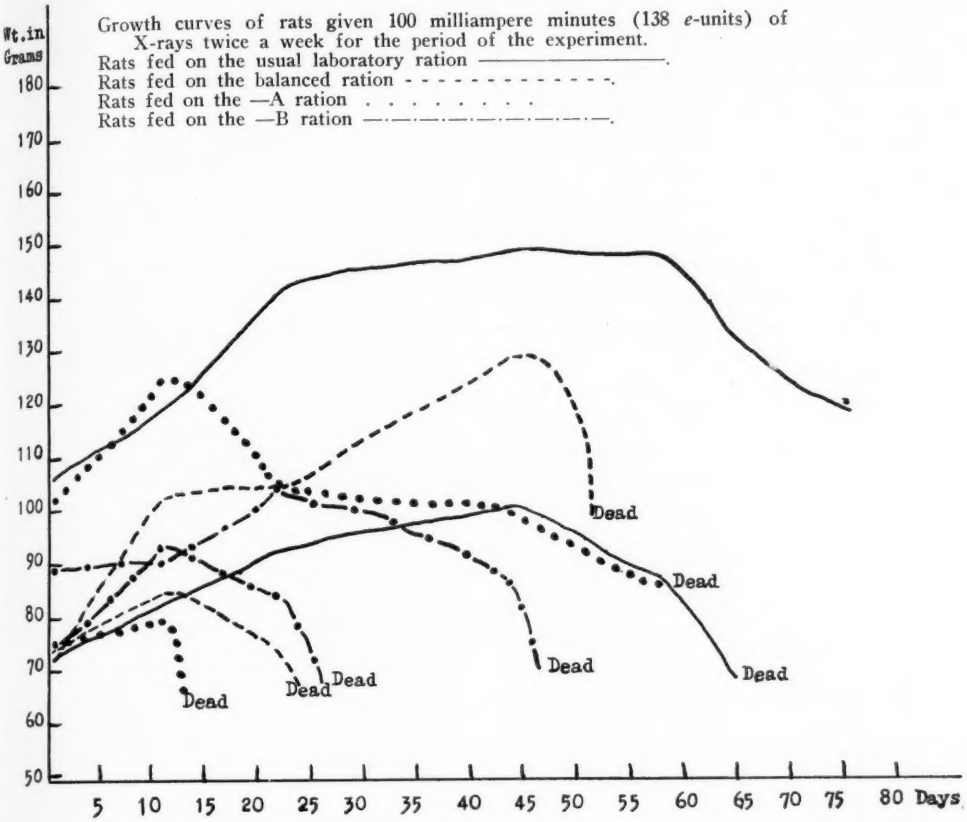
to the breakdown of the cells, these animals should be protected by increasing alone the Vitamin A fraction. In the studies on coal tar it has been shown that the general and local toxic action of this substance, as well as that of other lipoid solvents, may be prevented by increasing the Vitamin A fraction in the food (13) (14).

It is interesting to note in the Curves 1 and 2 that the rats survived for a long time on these high doses of X-rays only when given a complete laboratory diet. They succumbed quickly on a diet ample only in Vitamin A, as they succumbed quickly on a diet deficient in this vitamin. Those rats fed on a diet ample in both Vitamins A and B, the so-called balanced dietary, also succumbed at an early time. As must be pointed out, the so-called balanced dietary is balanced only in reference to fats, proteins, salts, and vitamins A and B. Rats on this diet do not breed after a short time and they never go through the normal span of life (2 to 2½ years) of our rats fed on the ordinary diet of vegetables, meats, grain, dog biscuits, and water.

The dietaries referred to above are as follows:

Balanced Ration

Potato starch	80 grams
Egg albumin crystals	50 grams
Salts (McCollum)	10 grams
Butter	30 grams
Vegex	10 grams



Curve 2. The effect of repeated doses of X-rays (138 *e*-units) on rats fed on various dietaries.

—A Ration

Potato starch	80 grams
Egg albumin crystals	50 grams
Salts (McCollum)	10 grams
Crisco	30 grams
Vegex	10 grams

—B Ration

Potato starch	80 grams
Egg albumin crystals	50 grams
Salts (McCollum)	10 grams
Butter	30 grams

While our results of the effect of well-rounded diets on the action of X-rays are not as yet completed, it must be stated here that the later experiments have been more striking than those reported in Curves 1 and 2. These facts have led us, therefore, to use a high dietary in treating patients. By a "high dietary" we mean one which contains not only ample or a large amount of Vitamin A, but other food constituents and vitamins. A preliminary report of the results of such treatment will also be given here.

RESULTS OF THE EFFECTS OF A WELL-ROUNDED DIETARY ON PATIENTS UNDER X-RAY TREATMENT

Cancer patients coming for treatment are often already suffering from cachexia. X-rays add temporarily to this condition. For some time we have given these patients

a diet rich in proteins, carbohydrates, cream, butter, cod liver oil, green vegetables, and fruit. We have also given them a small amount of wine or whiskey. This high dietary does not change the action of these rays on the cancerous tissues, but only on the normal tissues of the organism. This is not surprising because of the great reduction in blood supply to the cancerous tissue. We had already noticed this fact in attempting to arrest cancer by such dietaries. These studies have shown that the only effect on the cancer of such treatment is a slight slowing of its growth rate. The main effect of such a diet is to protect the individual against the anemia and cachexia which accompany this process.

In these same studies we have also noticed that patients who cannot take X-ray can be made sufficiently resistant by this treatment to withstand even long treatment with the rays. One leukemic patient was discharged from a hospital in Saint Louis and considered unfit for treatment, in March, 1924. We placed him on a diet rich in all food substances, but especially rich in Vitamin A. We also gave this patient old cultures of the *Pseudomonas tumefaciens*, which have a certain amount of lipoid substances acting as Vitamin A. He is still working hard every day and has worked during the whole period, except at a time when we removed several abscessed teeth. At this time he suffered from hemorrhage at the site of the removal of the teeth. We have given this man small doses of X-rays at times to maintain his spleen within bounds without affecting him sufficiently to cause him to stop his work.

Another patient with Hodgkin's disease, referred to us by Dr. Orndoff in November, 1925, has become resistant again to X-rays after being fed carefully for a few months. This man unfortunately is suffering from a chronic nephritis and consequently causes trouble at times. His Hodg-

TABLE I

Animals	X-ray Dosage Given Twice a Week	Balanced Ration	Diets	
			— B Ration	— A Ration
Rats	10 milliampere minutes (13 *e*-units)	Shortens life +	Increases growth and lengthens life +++	No effect
Rats	25 milliampere minutes (34 *e*-units)	Shortens life ++	Increases growth and lengthens life ++	Increases growth and lengthens life +
Rats	50 milliampere minutes (68 *e*-units)	Shortens life +++	Increases growth and lengthens life +	Increases normal growth and life +++
Rats	75 milliampere minutes (102 *e*-units)	Shortens life ++++	Rapid destruction of animal	Rapid destruction of animal
Rats	100 milliampere minutes (136 *e*-units)	Shortens life +++++	Rapid destruction of animal	Rapid destruction of animal

Showing the effect of measured doses of X-rays on animals fed on various diets. The + mark indicates the degree of change.

kin's disease has been kept apparently well under control, however, although he has suffered from this disease since 1917.

DISCUSSION

From these observations we have come to believe, therefore, that X-rays act to cause molecular disintegration in the cell. These rays appear to stimulate in small doses, because those protoplasmic disintegrations from which the energy for life is derived predominate in the picture. When larger doses are given this evidence of stimulation fails. This is well shown in Table I. This table is compiled not only from data obtained in the experiments reported in this paper, but from our earlier reported experiments.

Further evidence for this belief is shown by the fact that the animals given large doses of X-rays are not protected by the addition of Vitamin A alone to their diet, as is true for coal tar intoxication, but only when given a very good general dietary. The fact that it is necessary, however, that the Vitamin A fraction be high in this general dietary suggests, further, that the primary and most important splitting of the protoplasm is the separation of the ergusia, or Vitamin A, from it. The splitting of the protoplasm by X-rays must be similar, therefore, to that produced by a high concentration (S^4) of the archusia.

This latter fact has a very important practical application in that it indicates that it may be possible by a proper dietary to protect the patient against those large doses of X-rays needed in the treatment of cancer and other diseases, and prevent the permanent defects of normal organs which often follow such treatment. Our further studies have also indicated that it is possible by the use of such dietaries to continue the treatment of the patient who would be otherwise refractory.

CONCLUSIONS

1. X-rays act apparently to cause molecular disintegration in cells. Small doses accelerate activity in the body and in the cells in that they accelerate the normal molecular disintegration which liberates the energy for life more than other detrimental forms of disintegration. Larger doses destroy the more fundamental structural elements of the cell.

2. The resistance of an animal or a patient may be raised appreciably by the use of a well proportioned dietary, rich in Vitamin A.

REFERENCES

(1) Burrows, M. T., Jorstad, L. H., Lunsford, C. Julian, and Ernst, E. C.: Studies on the Biological Effects of X-rays and Methods of Measuring X-ray Dosage. Read before the International Radiological Congress, London, 1925.

(2) Burrows, M. T., Jorstad, L. H., and Ernst, E. C.: The Effects of X-rays on the Vitamin Needs of the Organism and Cancer. Radiology, 1926, VII, 279.

(3) Burrows, M. T., Jorstad, L. H., and Ernst, E. C.: Cancer, Vitamin Imbalance and Roentgen-ray Activity. Jour. Am. Med. Assn., 1926, LXXXVII, 86.

(4) Burrows, M. T., and Johnston, C. G.: The Action of Oils in the Production of Tumors, with a Definition of the Cause of Cancer. Arch. Int. Med., 1925, XXXVI, 293.

(5) Burrows, M. T.: Is Cancer a True Disease or Merely the Results of a Change in the Organization of the Organism? Radiology, 1925, IV, 407.

(6) Burrows, M. T.: Studies on the Nature of the Growth Stimulus in Cancer. Jour. Cancer Res., 1926, X, 239.

(7) Burrows, M. T., and Jorstad, L. H.: On the Source of Vitamin A in Nature. Am. Jour. Physiol., 1926, LXXVII, 38.

(8) Burrows, M. T., and Jorstad, L. H.: On the Source of Vitamin B in Nature. Am. Jour. Physiol., 1926, LXXVII, 24.

(9) Jorstad, L. H.: The Behavior of Coal Tar in Adult and Embryonic Tissue. Jour. Cancer Res., 1925, IX, 232.

(10) Burrows, M. T.: The Production of Malignant Ulcers in Rats. Jour. Mo. State Med. Assoc., 1923, XX, 145, and to appear.

(11) Steenbock, H., and Daniels, A. L.: Irradiated Foods and Irradiated Organic Compounds. Jour. Am. Med. Assn., 1925, LXXXIV, 1093.

(12) Hess, A. F.: The Ultra-violet Rays of the Sun. Jour. Am. Med. Assn., 1925, LXXXIV, 1033.
(13) Jorstad, L. H.: The Relation of the Vitamins to the Reaction Induced by Coal Tar in the Tissues of Animals. Jour. Exp. Med., 1925, XLII, 221.
(14) Jorstad, L. H.: The Action of Lipoid Solvents on the Organism and in the Production of Cancer. Jour. Cancer Res., 1926, X, 229.

The Dosage of Bucky's Borderline Rays in Roentgen Units with the Standard Instrument. Hans Küstner. Strahlentherapie, 1927, XXVII, 124.

The author has carried out extensive investigations regarding the dosage of X-rays of long wave length. A special chamber had to be constructed because the walls of the ordinary ionization chamber absorb too much of the intensity. It appeared that intensity and penetration of these long rays vary for different tubes, even if the same potential and tube current is recorded. The reason lies in the different thickness of the Lindemann window (special glass of low atomic weight). The inverse square law does not hold true for long rays because of the considerable absorption in air. It is necessary, therefore, to carry out measurements in the treatment distance. The special chamber, which is shorter than the usual type, has a window of Cellophan covered with graphite: 0.105 mm. of this material absorbs as much as 10 cm. air. The new chamber is independent from the wave length between 7–60 K.V. It is possible, therefore, to calibrate it in *R*-units. Measurements of the intensity distribution in Zellon were carried out, the results of which can be transferred to water. They show that in several millimeters depth considerable X-ray energy must be effective. Inasmuch as the penetration of these waves of long wave length varies with the potential on the tube quality, measurements should be undertaken (absorption analysis) rather than to depend upon the primary voltmeter. As an example, it is stated that one tube emitted at 9 K.V., 9 ma., 10 cm. F.S.D., in 7½ minutes a dose of 1000 *R*.

E. A. Pohle, M.D.

THE VALUE OF AN X-RAY STUDY IN THE CARE OF CASES SUFFERING FROM PULMONARY TUBERCULOSIS[1]

By H. KENNON DUNHAM, M.D., CINCINNATI

I HAVE long felt that when a clinician sought the aid of a roentgenologist, it should be as a consultant, and that the usual X-ray report fell short of its possible contribution to the diagnosis and method of treatment of tuberculosis.

The care and treatment of tuberculous patients is often expressed by the trite phrase —"rest, fresh air, and good food." This, like most phrases, needs interpretation. "Good food" is often wrongly translated into over-stuffing with special diets. "Fresh air" is prescribed as a walk around several blocks before breakfast. "Rest" is too often considered as doing no gainful work.

In contrast—the doctor who knows best how to treat pulmonary tuberculosis is that physician who knows best when, where, how, and why to put a patient to bed, and especially when, where, how, why, and how much to get that patient up. The technic of how to secure adequate rest for a tuberculous patient is difficult, and few men outside of a tuberculosis center or a tuberculosis hospital ever acquire it.

The point which I wish to emphasize in this paper is that the proper evaluation of the pathology, deduced from a study of chest plates, is an invaluable help in determining that most important "when, where, how, why, and how much a patient should rest."

Such additional adjuncts to rest as pneumothorax, thoracoplasty and special medication will easily fall into their respective places when the pathology of a given case is understood. With this knowledge you are in a position to advise intelligently as to the care and treatment of a given case, and every physician taking chest plates should be prepared to so advise in every case he is asked to examine. Otherwise he has not met his full responsibility as a consultant.

Some years ago, I presented to this Society an X-ray classification. I again recommend that classification.

Some of you may remember also that many years ago I called your attention to the fan, which is recognizable in most cases of adult pulmonary tuberculosis. I again recommend that you carefully study the fan, and understand its relation to the anatomy of the lung. It is caused by a lobular pneumonia, the result of inflammatory exudate within the lung, walled off and shaped by the septa. It usually lies just under the pleura. Its size, shape, density, and appearance vary with its age. Other etiological factors will cause a lobular pneumonia, so, to be characteristic of tuberculosis, there must be two or more of different ages, usually detected by different densities and shapes. You ask, Where is the tubercle that is the basis of all tuberculous lesions? I reply that the fan contains tubercles, but if you wait until they can be demonstrated on the plate, it will be an old process with which you are dealing. Let me repeat—it is common for tuberculous exudate to be absorbed, for scar tissue to be laid down, for the fan to contract and so for its density to increase. Caseation within the small tubercles often calcifies, and the pleura over such a lesion usually thickens. This is the common picture when small lesions undergo repair, but it is quite common for the exudate to be absorbed without evidence of fibrosis, calcification, or thickened pleura. On the

[1]Read before the Radiological Society of North America, at the Twelfth Annual Meeting, at Milwaukee, Dec. 1, 1926.

other hand, the lesions may be so virulent, or the resistance so slight, that cavitation sets in very soon. Such a case has a very poor prognosis, and any treatment which can do much good must be employed as promptly as possible. Cavities favor the growth of large numbers of tubercle bacilli. The mucus is coughed up, small infected droplets are aspirated into other bronchi, and we see the mottled picture of caseous bronchopneumonia, often miscalled "peribronchial tuberculosis."

This is the picture of adult pulmonary tuberculosis, first with the lesions which have undergone repair, and, second, with lesions which are rapidly breaking down.

There is a third picture which is very common—the picture of old, fibroid tuberculosis. Both upper lobes may be involved. The fans are in varying stages of repair and degeneration. Unless you have dissected such lungs, you may not recognize a single fan within the heavy mass. But they are there, compressed by contracting scar tissue. I like to speak of these fans as conglomerate fans. Often such an one contains one or more thick-walled cavities. The lower lobes become emphysematous. Emphysematous blebs should be looked for—they are more common than our X-ray reports would indicate. But that is another paper. Thickening of the pleura is common and dislocation of the thoracic viscera upward or to either side is the rule. Such patients often live as tuberculosis carriers for many years, to die of some other lesion. But when caseous bronchopneumonia develops, the prognosis is always grave, as this generally means the beginning of the end.

The adult as well as the child is subject to tuberculous pneumonia. This is due to a massive infection, which involves many lobules adjacent to each other, so that a large part of a lobe is flooded by exudate. Let us call this "confluent lobular pneumonia." The diagnosis should only be suspected from the plate. The sputum and blood picture must be carefully and frequently studied. When the diagnosis is confirmed, the lung should be collapsed as soon as possible, because such lesions always cavitate. Pneumothorax will compress the diseased area, facilitate the forming of fibrous tissue, and help to prevent the formation and aspiration of infectious droplets, which cause bronchopneumonia.

The basal type of tuberculosis is more common in the child than in the adult, but it is not fair to call it uncommon among adults. It frequently occurs among white, and is quite common among colored, adults. Still, I class it as a puerile type. Its study is most interesting because we know least about it. It appears upon the plate as a heavy mottling, quite similar to caseous bronchopneumonia, except that we have no apical fans of different densities or upper lobe cavities. This type is not limited to the lower lobes—it is often seen in an upper lobe. Such lesions may exist for a long time without râles, loss of resonance, or tubercle bacilli in the sputum. Many cases of carcinoma also simulate this density. The diagnosis is difficult, but, in making it, race should always be considered. Many of these cases are associated with tuberculous lesions in other parts of the body, such as tuberculous lymph nodes, fistulæ *in ano*, infection of osseous tissue or of the genitourinary system. Such lesions should be looked for. The prognosis is always very grave, yet the condition of the patient does not suggest this, except near the end.

I shall merely mention miliary tuberculosis, so that you will not think I have forgotten this type. Such cases are usually fatal, but I have had two cases of healed miliary tuberculosis come to autopsy.

The annular shadow should receive especial attention. When not an artefact, the annular shadow is usually due to cavity. Only a thin-walled cavity would be mistaken

or overlooked, and thin-walled cavities are very serious lesions. It is our custom to repeat sputum examination daily. If the sputum is positive, we collapse at once; if negative, we watch that case most carefully, and inject the sputum into a guinea pig. Until we can prove that the annular shadow is not due to tuberculosis, we are not relieved of our responsibility. Such a lesion is often seen in the upper third of the lower lobe and may be obscured by the hilum. Many cavities appear, disappear, and reappear. This is no proof that an annular shadow is due to a localized pneumothorax.

Resistance to tuberculosis varies with the individual and the race. We have very little knowledge of resistance which we can apply to an individual. At the Cincinnati Tuberculosis Sanatorium we have noticed that patients over thirty do better than patients under twenty, when the type and extent of the lesions are similar. We have noticed that the negro race shows very little resistance.

Activity, like resistance, has many unknowns. It is often said that, just from the plate, one must never include activity in the diagnosis. This is ridiculous. A cavity is active, a recent exudate or a spreading lesion must be active. It is often possible to go so far as to say from the plate alone that the sputum is positive. It is much easier to say that one case of pulmonary tuberculosis is active than that another one is arrested.

A prognosis should also be attempted. It will give the clinician an idea of your opinion. There are many chances of error, as will be understood. Other organs may have tuberculous or other infections, and you are reading only the lung pathology. A diagnosis of activity, a prognosis or a statement that tubercle bacilli will be found in the sputum, must not be taken too seriously. Such conclusions are deductions, not observed facts. The value of all deductions is in direct ratio to one's ability to observe and deduce. This ability varies, as is proven by the different opinions which accompany stereo-plates, sent to me from all parts of the country, for rereading and interpretation. The prognosis will be deduced from the type and extent of the lesion, the age, race, and resistance of the individual. As I have said, of resistance we know little and the virulence and amount of infection can only be guessed by the type and extent of the pathology.

In spite of these many unknowns, it is surprising how many times the prognosis is accurate and the expectancy correct when made from the plate alone.

To best read chest plates, one should know the age, race, and symptoms. With a series of plates, the following questions should be answered:

1. Diagnosis: Tuberculosis — doubtful—lesions other than tuberculosis—normal chest.
2. Type of lesion: adult apical or puerile.
3. Are the lesions extending?
4. Are new lesions developing in other parts of the lung—new fans or caseous bronchopneumonia?
5. Are the lesions becoming more or less dense?
6. Are the lesions breaking down?—cavitation.
7. Is the tuberculous exudate being absorbed? Has it disappeared?
8. Is scar tissue developing?—contraction.
9. Have old lesions been walled off by scar tissue?

With the answers clearly stated, we are ready to consider most cases of pulmonary tuberculosis. The greater the extent of the lesion, the more damage has been done, and the greater the infection. There is an exception in an old fibroid type, with great resistance, the patient surviving to die of other causes. If the lesion is not extending, exercise and rest should be prescribed, governed by the patient's pulse, temperature, appetite, general appearance, and physical signs. If the lesions are extending, the patient must be carefully controlled and put to bed, regardless of all other factors. This same ad-

vice holds true when new lesions are developing. These may be in the form of lobular pneumonia (new fans) or caseation—bronchopneumonia. If the patient develops fever, rapid pulse, is sick, and the plates show no new lesions, look for other infection, but suspect generalized tuberculosis. Given these same findings with an indigestion and abdominal tympany, look for indigestion, but suspect tuberculous enteritis. It is very common. Negative plate findings, as above, are very helpful.

This example just described illustrates but one value of a negative plate. Another is profuse expectoration, negative sputum, severe cough, possibly blood-spitting, with nothing on the plate except possibly some heavy trunks to the bases. This is bronchiectasis and can be easily so proved by injections of lipiodol. There are varying degrees of bronchiectasis, and the treatment should not be postponed until we have three-layer sputum.

If the tuberculous lesions are growing heavier but not extending, that is a good sign. If they are extending or breaking down, while the patient is taking full rest, it is bad, and pneumothorax should be considered. Many cases reach their maximum degree of improvement and remain stationary. That is, they do well in bed, but become active upon exercise. Some of these are largely unilateral cases. This is true of some cases that have received pneumothorax. These are the cases for whom thoracoplasty should be considered.

I wish to break the thread of thought here, to call your attention to the great value of the plates in showing so much of the lung fields. Thus we help the clinician who finds that his original lesion is improving, but that he has overlooked a new lesion which has recently developed in another part of the lung, indicating need of absolute bed-rest. And we may assist the surgeon by warning him that his patient has a tuberculous lesion. Such a patient must not be subjected to undue shock. If the lesions are active, it is most probable that a general anesthesia will cause the aspiration of infectious droplets which will produce caseous bronchopneumonia in other parts of the lung.

If a patient's temperature is normal, the pulse not very fast, and the appetite good, take a set of plates. If you find that the exudate has not spread, and possibly has slightly absorbed, that is good, but have the doctor continue the rest. Explain that the patient is doing well, but complete arrest has not occurred, regardless of favorable signs and symptoms.

In cases in which the exudate has been absorbed, so that it no longer reaches the pleura, or in which there is evidence that scar tissue has been laid down, the fan is contracting, and no new lesions have developed, the physician may be advised that the patient has so improved that graduated exercise may be instituted. He should further be advised that the most important time in the treatment has been reached, that he should see the patient oftener, take the temperature and pulse oftener—and have plates taken more often, too. For lack of increased care over this important period, many cases relapse.

If you would bring this need of adequate and prolonged rest to your consultant and his patient, I recommend that you demonstrate the size of the lung lesion, and ask the clinician how long he would expect to immobilize such a lesion in the hip joint. Explain that the lung will heal no faster than the bone. Show him that the patient must not be allowed to act according to his feeling of strength, because there are no pain nerves in the lungs to give warning, and that there will be no apparent lack of lung function, because each of us has been given five times as much lung tissue as is necessary for aëration. Such patients are not toxic—

have no symptoms to indicate their real pathology. The most accurate estimate of this pathology is obtained from our plates.

Since prolonged and adequate rest is the fundamental principle underlying all treatment for pulmonary tuberculosis, and since lung pathology, during life, can best be studied from the plates, it is the roentgenologist's responsibility to decree that rest. He must master the problem, take a strong stand and in no uncertain terms prescribe the amount of rest that is needed. Then "rest, fresh air, and good food" can be considered with a new meaning for many physicians, and a great number of lives will be saved; then the roentgenologist will have so completed his task as to become a trustworthy diagnostician and an able counselor.

DISCUSSION

DR. T. D. CUNNINGHAM (Denver): Speaking of Dr. Dunham's paper, I can only agree with him in what he says about the use of the X-ray in the treatment of tuberculosis. The only disadvantage is in the case of the private patient. The patient in the sanatorium can have an X-ray examination without additional cost, and have it every three months or oftener—it is a valuable way to study the conditions. However, in the case of patients who are not so poor as to go to a free sanatorium or so rich as to have sufficient means to justify repeated examination (and in that group is the large majority of the earlier cases of tuberculosis, because, later on, most of them gravitate into the sanatorium)—these people are denied the very best form of treatment. Of course, this does not apply only to tuberculosis—it applies to practically all diseases. However, serial X-ray examination is the ideal way to follow a case of tuberculosis.

I can agree with everything Dr. Bettman said in the paper he read on Acute Empyema,[1] except the waiting for an encapsulated empyema to rupture into a larger one—that may prove disastrous. It is difficult to say how thick your lesions are around this encapsulated empyema. I have followed several cases in which encapsulation took place following drainage, and I can say that the X-ray is our most valuable adjunct in correct diagnosis, but it does not seem that we can do away with the aspirating needle or the various other means which have been of use heretofore. In fact, I should recommend always the aspirating needle before the surgeon proceeds to operate; otherwise you will find him going in on one side, too far away, and trying to touch the encapsulated empyema from some position where he cannot possibly do it. The only safe procedure is to find out by the use of the aspirating needle where this pus is, and it sometimes requires ten to twelve aspirations to locate it. When it is located, it should be drained. Following the course of an empyema case with the X-ray is not necessary, if the patient is doing well, and the internist and the X-ray specialist seldom see the cases that do well—they call us in only when they are in trouble. Surgeons will frequently operate on cases without the benefit of the X-ray, and we see only the cases in which they have fallen into serious trouble. Occasionally these cases of empyema drain, as Dr. Bettman has mentioned, some time later, but that is rare, and I agree with him that the closed method is the most valuable one for draining an empyema.

DR. W. W. WASSON (Denver): I do not care to enter into a formal discussion now, but I would like to emphasize the method of study that Dr. Dunham has carried out in regard to his chest cases. The man who sees the beginning of a thing and follows it through, is the man who gains the real

[1] Acute Pleural Empyema; A Clinical Radiological Study. Ralph B. Bettman and Robert A. Arens. RADIOLOGY, February, 1928, X, 153.

wisdom. A serial study of the chest is the best way to formulate ideas in regard to what constitutes real pathology. So often we see a small shadow in the chest that will pass almost unnoticed, and yet, if we were to take serial radiographs from month to month or from week to week, according to the case, we would observe changes as they take place—the extension of these minute shadows. Again, if we have other shadows, more discrete, and we take films from month to month, we will find that they remain discrete and do not change. In that way we can build up our knowledge of the shadows of the lungs—we can study living pathology. We must remember that the radiograph can be utilized not only to show normal anatomy, but its physiological and pathological variations.

Dr. M. C. Sosman (Boston): I think there is one point that Dr. Sante[2] did not stress sufficiently, and that is the pure mechanics or physics of the negative pressure in the thorax. He has three theories based on pathology, one on physiology, none on purely physical principles. These cases of massive collapse act exactly like the foreign bodies Manges has shown us again and again, blocking one bronchus. Dr. Sante reports that two of the cases, when they were turned on the sound side, and coughed, cleared immediately. Chevalier Jackson reports two cases in which, on removing thick mucous secretions from the bronchus, an immediate clearing of the affected lung followed. I would like to report another case which cleared almost instantaneously when the patient coughed up a large amount of thick mucous secretion. In other words, is not this the simplest possible explanation—a block of one bronchus by inhaled secretions, or, possibly, secretion due to some peculiar organism which produces a large percentage of mucus? That seems to me to be the most obvious explanation. Backing it up we have the fact that, in the 65 cases collected, the atelectasis was in the right lung four times as often as in the left—remember the well known frequency of foreign bodies falling into the right lung. Secondly, we took one of these patients under the fluoroscope and give him a large dose of cocaine—with not the slightest effect on the lung. We took a second patient and gave him a large dose of adrenalin, so large that his knees shook and he had to sit down, but there was no effect on the collapsed lung. I maintain that the cause of massive collapse is a purely physical block of one bronchus or part of one.

In regard to Dr. Dunham's paper, may I ask a question? What part of this large bronchial pneumonic exudate, as he calls it, is due to hemorrhage? We have been studying a series of cases of that type, and we have seen some of them clear so rapidly—in a matter of two or three days—that we think a certain number of them must be due to hemorrhage in the alveolus and not to actual inflammatory exudate.

Dr. L. T. LeWald (New York): I am inclined to agree with Dr. Sosman and his mechanical theory. Dr. Lemon,[3] at the Mayo Clinic, has done some experimental work which bears it out. He put some dogs under ether anesthesia in the same method and for the same length of time in use in the average abdominal operation, except that he placed a transparent cannula in the trachea, so that he could see—just as you see in your water gauge in the steam boiler—what happened to the secretion in the trachea, and he saw the secretion gradually travel down into the bronchi. I know that Dr. Lemon's experiment has not been given very much publicity, but it certainly seems to bear out the contention that massive collapse is a mechan-

[2]Massive Collapse of the Lung, with Report of Three Unusual Cases. L. R. Sante. Radiology, January, 1927, VIII, 1.

[3]Arch. Surg., January, 1926, Part II.

ical blocking of a bronchus, followed by absorption of the air in the lung.

DR. DUNHAM (closing): I want to pay my respects to the other speakers in this symposium—I have enjoyed every minute of it. Dr. Sante's paper was particularly interesting. I wish, when he closes, he would give us the report of the pathologist on that first case. I would not be able to make that diagnosis—I hope he will take a few moments to tell us about it. If you will notice how much he stresses the dislocation of the chest. This is found in many cases of carcinoma of the lungs. There is a physiological principle underlying the whole lung picture; there is some power that the physiologists have never explained, of keeping that lung expanded, which is much beyond the mechanical theory we have had given to us so long, *viz.*, the negative pressure. This physiological action you can see all through your studies of lung plates.

As to the cost of taking serial X-ray plates, I can only say that it is our duty to educate the whole country—physicians and people alike—to the need and the value of such a study as I have tried to present, because it will save the lives of many patients.

Answering Dr. Sosman's question, I want to say that none of these cases had had a hemorrhage. I am glad that he asked the question, so that I can say definitely that these remarkable clearings of the tuberculous areas are really the result of tuberculous exudate which has absorbed. There is a great deal more absorption of tuberculous exudate than is generally recognized.

DR. SANTE (closing): Since it is practically "up to us," as roentgenologists, to recognize this condition of the massive collapse of the lung, I think it may be well if I occupy a few minutes in reiterating the characteristic roentgen findings. The collapsed lung becomes dense—just as dense as a lobar pneumonia. Why, I do not know. A lung collapsed to a smaller size in association with pneumothorax does not present this same density. Why not, I do not know, and I do not think it has ever been satisfactorily explained. In taking on this smaller size, the chest, of course, being an elastic closed cavity, the chest wall will sink in to compensate for the space lost by the collapse of the lung, and this sinking-in process is evidenced by a narrowing of the chest walls on the affected side, approximation of the interspaces, elevation of the diaphragm, and the drawing over of the heart and mediastinal structure toward the involved side. If the entire lung is collapsed, the heart shows the most obvious displacement, and it is the displacement of the apex beat of the heart that is the key to the diagnosis for the clinician. But when the collapse involves a single lobe, as the first case I showed, the heart is not displaced, the chest is not materially narrowed, because all that happens is that the lower lobe of the lung really expands a little more. There is the characteristic thing which the radiologist can point out but which the clinician cannot—the fact that the trachea has deviated towards the affected side.

In support of my belief that the condition is not due entirely to a blocking by secretion, first, just consider the cases in which there have been no injuries whatever, and then consider the fact that there has never been a case reported after a tonsillectomy or any nose or throat operation—conditions in which aspiration of large quantities of blood and mucus is manifestly present. Hundreds of tonsillectomy cases have been bronchoscoped immediately in the lower stem bronchi, and never has there been a case of massive collapse reported as following aspiration. Likewise, cases have followed operations where there was no general anesthetic given at all, not even morphine,

but a local anesthetic; for instance, a herniotomy. Cases have followed spinal anesthesia, and cases have resulted where there was not even an injury. Fracture of the femur has been followed by the condition. There is some other process at work with which we are not quite familiar.

Long before massive collapse was described in the literature, Lichtheim described conditions that occurred in the lungs of animals after the occlusion of a bronchus by a bean. He found that if the bronchus was completely occluded, within a short time there would be complete atelectasis of that portion of the lung supplied by that bronchus. If the blood supply to this portion of the lung was cut off, this absorption of the air and atelectasis did not follow. He concluded that the air so entrapped was absorbed by the circulating blood—a fact well recognized by physiologists. I am well aware of the fact that in the horse and the ox actual constriction of the lung has been demonstrated—by stimulation of the vagus nerve, I think—and in smaller animals by stimulation of the lung direct. William Snow Miller has shown that there are muscle fibers in the smaller bronchioles, and nerve fibers which supply them. I do not think that this condition is due to a continuous spasm; I think it is due to a more or less transitory spasm of the bronchioles during the period of interruption to the vagus supply, say, during an abdominal operation, and that the walls of the bronchioles, once collapsed, become adherent on account of their mucous surface, and that the atelectasis follows absorption of the remaining air by the circulating blood. Once established, this condition is maintained for a varying period, say, of days or weeks. It may be readily explained, since these mucous surfaces, once approximated, are held together by cohesion until they are disturbed.

There are two ways in which they may be disturbed: (1) By rolling the patient, putting him in some unusual position so as to cause a stress between these two surfaces, to pull them apart, so that just a small amount of air is introduced, and, as soon as that is started, re-inflation occurs very quickly. Air will go out to the terminal bronchioles. That is the condition which happened in our cases when we rolled the patients upon their unaffected sides. The other condition (2), in which the patient is made to remain quiet, carefully taken care of and not allowed to move, Nature itself will take care of, but in a different way. In the histories of all of these cases which I have studied, I find that the expectoration and spitting of pus and mucus begins coincident with the development of fever, which is usually three or four days after the collapse is established. I think it is due to the fact that the collapsed mucous membrane prevents the discharge of pus, which forms from infection. The two surfaces are mechanically separated by the pus and mucus —small bronchioles become inflated one after the other, resulting in a patchy appearance of re-inflation throughout the lung. This is a slow process, requiring weeks, but finally results in the same ultimate re-inflation.

So I believe there is a nerve impulse to the lungs and a possibility of a transitory spasm. This spasm to the bronchioles is not necessarily maintained over the entire period of the disease, but, once established, can remain —from an entirely mechanical standpoint— without any further pathological process.

In the literature many cases have been reported wherein the pressure has been taken inside the chest, and it is a very marked negative pressure. Dr. Sosman's explanation, attributing this condition entirely to blocking of bronchi by secretion, I think we must consider from another point. We have all seen cases similar to the one I am about to describe. A girl, suffering with

an intestinal obstruction, was given barium sulphate by mouth. She aspirated the barium into every portion of her lungs, and this without very much discomfort. It remained in the lungs for days—she was so analgesic that she did not have "pep" enough to cough it up. Yet, never, in such cases, has a condition of collapse developed.

Paralysis of the diaphragm cannot be the explanation. We have had a number of cases in which phrenicotomy was done, a section of the phrenic nerve resulting in paralysis of the diaphragm, as a method of treatment in tuberculosis, yet never in these cases have we seen this condition develop. Besides, you do not get paralysis of the diaphragm in these cases—it is not paralysis, it is immobilization. Paradoxical action of the diaphragm—the phenomenon encountered with paralysis—is not present here. It is immobilization in a high position, evidently a defense reaction. This high position is maintained after the lung is completely re-inflated, so there is some other factor with which we are not acquainted.

Dr. LeWald maintains his belief that the condition is due to aspiration. The same answer will suffice for Dr. LeWald's statement and for Dr. Dunham's question: the autopsy in our first case was done entirely irrespective of the X-ray findings, and without representation from our department being present. We did not know it was going on. I will read some excerpts from the paper which bear on this point. [Read an excerpt from his paper.] I have a photomicrograph of the lungs to show the atelectatic condition. The autopsy was made by the Pathological Department of the St. Louis University Medical School.

ELEVATION OF THE DIAPHRAGM[1]

By FREDERICK W. O'BRIEN, M.D., BOSTON

ELEVATION of the diaphragm may be temporary or permanent: it may be congenital or acquired: it may be symptomless—more often it is associated with such grave symptoms that surgical interference is imperative.

The diagnostic significance of the elevated diaphragm seems very well appreciated by the roentgenologist, but his viewpoint does not seem to have been accepted generally, doubtless because he has not been convincing. I have in mind particularly the diagnostic significance of the elevation of the diaphragm as seen by X-rays in subphrenic abscess and diaphragmatic hernia; the former, at least, with an excessive mortality, the result of late diagnosis and still later operation.

Temporary elevation of the diaphragm occurs in pneumonia, lung abscess, subphrenic abscess, liver abscess, diabetes, Banti's disease, during digestion, and normally at full expiration.

Permanent elevation of the diaphragm may be seen in eventration, unoperated-upon diaphragmatic hernia, mediastinal tumor, aneurysm, chronic tuberculosis, and any condition with permanent involvement of the phrenic nerve.

Because of its muscular tendinous structure, the diaphragm lends itself readily to X-ray investigation, its opaque, convex contour standing out in relief to the radiant lung fields above it. Both the roentgenoscopic (fluorescent screen) and roentgenographic (photographic film) methods should be utilized; the former, for actual observation as to the functioning of the diaphragm as well as for differential diagnosis of gross intrathoracic conditions; the latter, for permanent record and study of patients too ill for examination by the screen method.

At the risk of relating the obvious, let me recall that the diaphragm is a single, independent, thin, markedly dome-shaped muscle stretched across the inferior aperture of the thorax in such a way that it is convex toward the thorax and concave toward the abdomen. It consists of two parts: a central tendinous portion and a peripheral or muscular portion. It is the chief muscle of respiration. By the contraction of its fibers, the domes of the diaphragm are drawn downward and the costal portions are drawn away from contact with the thoracic wall so that the thoracic cavity is increased in size and the abdominal cavity is diminished. It is enervated by the phrenic, the lower costal nerves, and the phrenic plexus of the sympathetic.

Preliminary survey of every case—when practicable—with the fluorescent screen is most desirable. Normally, the right leaf of the diaphragm will be seen one interspace higher than the left, bow-shaped. The highest point of the arc or dome in the adult standing patient will be found, on the right side, to be approximately at the upper edge of the fifth rib, and on the left, at the lower edge of the fifth rib. On breathing, both leaves move synchronously. In the long-chested individual, the diaphragm will be somewhat lower, flat, less dome-shaped, with a shallow costophrenic sulcus; while in the stocky type, the diaphragm will lie higher, be more dome-like, and with a deep costophrenic sulcus.

The excursion of the diaphragm will vary with the type of breathing, whether costal or abdominal, whether quiet or forced,

[1]Read before the Twelfth Annual Meeting of the Radiological Society of North America, at Milwaukee, December 1, 1926.

whether the individual be standing or lying. In quiet breathing, Williams (1) determined the average excursion to be about 1.25 cm. when both lungs are normal, but if one lung has to do more than its share of work, the diaphragm on the well side has a greater excursion. The average excursion between expiration and full inspiration is 6.8 cm. on the right side and 7.1 cm. on the left side. In the recumbent position, there is a marked decrease in the extent of the diaphragmatic excursion. On deep inspiration, at times, the mesial half of the right diaphragm may be noted to be elevated, due to elevation of the central tendon. Such an appearance has been mistaken for liver tumor and new-growth of the lungs. Usually, it disappears on deep inspiration. The right leaflet of the diaphragm may be seen clearly in its entirety, resting on the liver. The inner border of the left leaflet is obscured by the heart shadow, except during forced inspiration.

The position of the diaphragm, its shape and degree of excursion as observed by X-rays is the important diagnostic triad. This, combined with the X-ray signs of the presence or absence of disease above or below the diaphragm, correlated with the clinical picture, is of such diagnostic significance as to be pathognomonic in subphrenic abscess and diaphragmatic hernia.

I have seen six cases of subdiaphragmatic abscess and one liver abscess during the past eight months, in which the diagnosis was based on X-ray signs correlated with the clinical history. Four of these came to operation; the abscess found and drained, with no mortality. Two cases were discharged, well, without operation. One case came to autopsy—a typical gas-abscess case, in which the medical consultant did not share the view of Pancoast (2) that the X-ray diagnosis of subdiaphragmatic abscess is a comparatively simple matter.

But that the diagnosis of this disease is an important matter becomes all too plain when one realizes that between 85 and 100 per cent of all cases not operated on die.

Two kinds of subdiaphragmatic abscess are seen—the so-called simple type and the gas-containing abscess. Both kinds of abscess may occur below either diaphragm. The abscess is almost always unilateral, due to the natural protective barrier of the falciform ligament which prevents extension from the right to the left, and *vice versa.*

The location of the abscess depends usually on the primary etiological factor, whether or not it is the result of direct infection by soiling or an infection from a distant focus. Two-thirds of the cases examined by Lockwood (3) were the result of soiling from a viscus within the abdomen, either before or following operation; one-sixth, from extension of adjacent abscess; one-sixth, the result of distant foci, such as carbuncle.

Abscesses of the hepatic flexure and of appendiceal and duodenal origin form to the right of the suspensory ligament, which is the dividing line, and cases of perforation of the stomach and infection of the spleen and pancreas form to the left.

The mode of spread may be by direct extension, by gravitation from a general or localized peritonitis, or by direct extension from the lower peritoneal fossa through the portal vein or lymphatics or blood stream. All investigators of the subject place great weight upon the part played by gravity, especially in the post-operative cases.

Attention is drawn to the division of the posterior abdominal wall into certain well-marked water-sheds; longitudinally, by the spinal column; transversely, by the muscles of the loins, the kidneys, and perirenal fat; the transverse water-shed separating the subphrenic pouches above from the pelvic cavity below. In the male, these subphrenic pouches are not easily drained if they contain peritoneal fluid. In the female, the

paracolic groove allows drainage into the pelvis more readily.

The organisms usually found are *bacillus coli* associated with *streptococci* and various types of *anaerobes*. The abscess containing pus and gas usually follows rupture or soiling from a hollow viscus.

Subphrenic abscess may occur at any age. Norris and Landis (4) refer to a case reported in a patient aged fifteen months.

The abscess is usually intraperitoneal. It may be outside the peritoneum in hepatic, renal, and certain appendiceal cases where infection spreads upward in the cellular tissues behind the ascending colon, says Boyd (5).

The pathological process, according to Lockwood, is one of infection, liquefaction, necrosis, and pus. He states that it requires about two weeks for the abscess to wall off; therefore, earlier transpleural drainage should not be considered. Gas was present in approximately one-third of the three thousand cases examined by him.

The physical signs may be complicated by upward extension of the process through the diaphragm, giving rise to serous pleurisy or empyema.

The most helpful signs and symptoms gathered by Lockwood are the following: (1) That more than two-thirds of the cases of subdiaphragmatic abscess follow operation, and the condition should be suspected at once in a patient who maintains, for no obvious reason, an elevation of temperature and pulse after operation. Also, a patient giving a long history of symptoms associated with the stomach, duodenum, gall bladder, or appendix that has not been operated upon should be suspected. (2) That while there is a varying degree of temperature, there is usually a marked variation, the so-called "church-steeple type," with an increase in pulse rate and a respiratory rate not in keeping with either the temperature or pulse. Pain at the costal margin referred to the back and frequently to the shoulder, deep pain elicited by pressure over the costal margin from the front to the back or from side to side. The leukocyte count varies; it is usually high in acute cases, but there may be a leukopenia in the insidious type or in patients in the advanced stage of emaciation or with low resistance. Sweats, rigors, short catchy diaphragmatic cough, and vomiting and hiccoughs occur in 50 per cent of the cases. There is progressive emaciation and weight loss. In 60 per cent of the cases, inspection will reveal a mass bulging in front laterally or posteriorly. The abdominal thoracic movement is limited on the affected side, the interspaces over the abscess may be retracted, the liver may be pushed downward.

The physical signs in the cases seen early are dullness on percussion, diminished breath sounds, pleural friction rub. As the abscess develops, the rub may persist or disappear, with an increase in the area of dullness. Percussing down the back, there will be normal resonance, then increasing dullness due to compression of lung, then dullness due to pus, and, if gas is present, an area of hyper-resonance, then absolute dullness over the liver.

Examination by roentgenogram and roentgenoscope will reveal the following X-ray evidence of disease: Simple subdiaphragmatic abscess (non-gas-forming type) without complications above the diaphragm will show on the X-ray screen or film an elevation of the diaphragm on the affected side in marked disproportion to that of its fellow. The contour of the diaphragmatic dome will be found to be smooth and regular, the costophrenic sulcus clear, the lung fields normal and radiant. On screen examination, the diaphragm will be found to be immobile on the affected side. In the differential diagnosis, one must consider the normally high-placed diaphragm of the stocky individual; also, the reflex inhibition

of the diaphragm which permits it to remain in the expiratory position in pleurisy without effusion and lobar pneumonia. The correlation of the history with the X-ray findings will be a guide here, and, as Wessler and Jacques (6) point out, the displacement of the diaphragm will depend on the amount of fluid in the subphrenic space and its relation to the diaphragm. One should remember that pus on the posterior aspect of the liver or a perinephritic abscess may not influence the height of the diaphragm to any extent. If the abscess is on the left side, the level of the diaphragm may equal that of the normal diaphragm on the right side or be considerably higher. The air-bubble of the stomach seen on the left beneath the diaphragm in the presence of subdiaphragmatic abscess may be obliterated or transposed far to the left. Its position may be definitely determined by filling the stomach with air or a contrast medium.

In the gas-containing type of subdiaphragmatic abscess without complications above the diaphragm, the diaphragm on the affected side will be found immobile, higher than normal, its contour regular, the costophrenic sulcus and lung fields clear, but, in addition, beneath the diaphragm will be found a semicircular area or clear space. On the X-ray film, it will appear as a half-circle of darkness; on the fluorescent screen, as a half-circle of brightness, which means an area easily penetrated by the X-rays. The horizontal axis of the half-circle defines the fluid level, the clear space above corresponding to the area occupied by gas. That one is dealing with a fluid level may be demonstrated by the roentgenographic method as well as by the screen, upon examining the patient erect and in the lateral position. Succussion under fluoroscopic observation will dramatically visualize the change in fluid level. If the patient is examined prone, this diagnostic point may be entirely obliterated. Even patients too ill to be examined in the erect position are seldom so invalided that they may not be turned on their well side and an examination made by horizontal rays to demonstrate a fluid level which otherwise might be missed.

The most common complication of subdiaphragmatic abscess is pleurisy with effusion, usually seen in the gas-abscess type, because, by the time there has been decomposition of the abscess cavity products, there has usually been a pleural transudate. In very protracted untreated cases, there may be a rupture of the abscess into the pericardial sac or general peritoneal cavity.

In simple pleural effusion as seen by X-rays, the diaphragm is low, not elevated. It is flattened, not dome-shaped. The costophrenic sulcus is not clear or is entirely obliterated. There is also a crowding of the heart and the mediastinal contents to the opposite side of the effusion.

Liver abscess uncomplicated by subphrenic abscess is accompanied by a moderately high diaphragm, whose movement is restricted. I have seen one case of Banti's disease with high left diaphragm, quite immobile, but, with the physical signs and clinical picture, the etiology of the elevated diaphragm was clear. Newgrowth and gummata of the liver usually affect only a segment of the diaphragm. Pneumoperitoneum as developed by Stewart (7) may be of distinct value in differential diagnosis, but is not to be recommended in any acute suppurative lesion. One case examined by me and thought to be newgrowth was proved by pneumoperitoneum to be localized hernia of the right leaf of the diaphragm.

If there exists any suspicion of subphrenic abscess, an exploratory puncture may be made under fluoroscopic control, as suggested by Sommer (8), although Fifield and Love (9) believe this diagnostic procedure should be employed only in the operating room.

Sommer suggests making the gas-free abscess gas-containing by withdrawal of 30 c.c. of fluid and the injection of the same quantity of air. In the complicated case, punctures at different levels are advised. If different kinds of puncture fluid are obtained at different levels, the diagnosis is rather certain.

Phrenic paralysis, neuritis, and poliomyelitis may give one a high diaphragm, due to paralysis of the muscle in expiration. There should be no difficulty about differentiating the high diaphragm due to tumor of the lungs, mediastinitis, aneurysm, and chronic tuberculosis.

The other group of related cases includes diaphragmatic hernia and eventration. Eventration is very rare; diaphragmatic hernia is far more common than was supposed, and not by any means as symptomless as historical literature would lead one to believe.

Hernia of the diaphragm may be congenital or acquired. Some attempt has been made to further classify it as "true" if there is present a sac made up of peritoneum or pleura or both, and "false" if without a sac. This may well remain an academic question, while we turn to the practical aspects of the matter. Hernias of the diaphragm may be traumatic or non-traumatic. If the latter, they usually occur through the natural openings, mostly esophageal. By traumatic hernia, I understand such as follows a penetrating wound or a crushing injury, which would produce a rupture of the diaphragm and greatly increase abdominal pressure. By non-traumatic, those cases in which there may have been a congenital weakness, but in which the hernia did not manifest itself until later in life, developing gradually as an inguinal hernia may. In congenital cases, the defect is the result of faulty development. If the defect is extreme, the condition is one that is incompatible with life and is met with in stillborn children. The acquired non-traumatic types occur through the preformed openings of the diaphragm or at their margins.

Traumatic hernia may occur anywhere, but is usually seen on the left side. As Norris and Landis point out, there are two reasons for this: (1) The manner in which the injury commonly occurs. (The wound is usually inflicted by a right-handed person striking at the most vital and most vulnerable part of his opponent, namely, the left side.) (2) The presence of the liver on the right side acts as a plug if an opening is made. Hedblom (10) defines diaphragmatic hernia in a very practical and diagnostic manner when he says that it is a transdiaphragmatic evisceration of the abdominal contents into the thorax.

Eventration of the diaphragm is not, strictly speaking, a true form of hernia, but is usually considered in conjunction with hernia of the diaphragm. It is relatively rare and is characterized by a general expansion of one-half of the diaphragm, allowing the abdominal viscera to be displaced upward into the thoracic cavity. It consists essentially in a great thinning-out and weakening of the musculature of the diaphragm on one side, almost always the left, so that the dome rises in the chest, often up to the level of the second rib, while the abdominal viscera rise to occupy the space below. Richards (11) follows the classification of Lerche and divides eventration into congenital and acquired; acquired being such as would follow an acute infectious disease and affect either the diaphragmatic muscle or the phrenic nerve. The weight of opinion is in favor of its congenital origin. Eventration differs from hernia in that the contour of the affected dome is not irregular. There is neither a bulging nor a localized opening.

Eventration of the diaphragm, because it is rare and relatively unimportant, I will consider first. Morison (12), of Man-

chester University, has examined this condition and reported on it at length. On screen examination, it presents a striking picture. The elevated diaphragm is seen to extend high up into the chest, forming a dome, the upper boundary of which extends as an unbroken line across the left hemithorax, a condition which is maintained in all positions. This unbroken bow-line encloses an air space—the air-sac of the stomach—at the bottom of which is often a sharply defined horizontal line, its height depending on the amount of food in the stomach. The upper level of this line is always that of the cardiac orifice. If there are no adhesions to the lungs, then the movements of the bow-line—the thinned-out diaphragm —are seen to be reversed during the respiratory act, moving upward with inspiration and downward with expiration. To this phenomenon, the term "paradoxical respiratory movement" has been given. Morrison found this in all his cases. The thinned-out diaphragm having little or no muscular tissue in it, being merely a fibrous structure, covered on one side by peritoneum and on the other by pleura, cannot contract, and so is subject to the mechanical forces of respiration. The contents of the dome vary. The air-sac of the stomach is always present, and may occupy the whole of the dome. There may be rotation of the heart, not to be mistaken for a true dextrocardia, and well marked deformity of the stomach. This condition Morison did not believe had been previously described—the stomach presenting two sacs, the upper spilling forward into the lower due to the ascent of the greater curvature of the stomach under the elevated diaphragm, with rotation on a more or less fixed point. The two important signs are the unbroken bow-line of the diaphragm, with the air-sac of the stomach immediately below it. "Paradoxical respiratory movement" is seen in diaphragmatic hernia. In hernia of the diaphragm, where there has been evisceration of the stomach and partial strangulation of it, the stomach appears like an hour-glass.

Morison states that he has seen nine cases of unilateral phrenic paralysis which could not be differentiated from eventration of the diaphragm radiologically. This is the type which he speaks of as "acquired eventration." In two cases, the right phrenic nerve was involved and in seven of them, the left. Three of the cases occurred with secondary carcinoma of the mediastinum and two others were secondary to carcinoma of the breast. Of the remaining cases, three were associated with pulmonary tuberculosis, two with growths in the chest, and one with aneurysm of the aorta. In his two cases that came to postmortem examination, the diaphragm showed degeneration of the muscle fibers, but the changes were not so advanced as one would have expected.

Diaphragmatic hernia, as seen on the fluorescent screen and roentgen film, will show an irregular, elevated, broken line extending across the affected hemithorax, with an increase in the deformity when the patient is prone. There will be a prolapse of the viscera into the pleural cavity through the gap in the diaphragm, this prolapse or evisceration being reduced upon the patient assuming a standing position, except in cases where there is strangulation. "Paradoxical respiratory movement" may be seen in diaphragmatic hernia and depends in great measure on the extent of the diaphragmatic tear and the amount of prolapse. Besides these X-ray signs, in traumatic diaphragmatic hernia, there will be a history proportionate to the injury, such as fractured rib, hemothorax, and collapsed lung.

A traumatic hernia of the diaphragm of any moment will give immediate symptoms. I have seen one patient with fractured ribs, hemothorax, ruptured kidney, ureter and bladder, who presented no symp-

toms after two years except a feeling of intrathoracic pressure on lying down.

The non-traumatic acquired type of diaphragmatic hernia is of recent interest. It is difficult of recognition. L. B. Morrison (13) and T. R. Healy, of Boston, were the first to report any considerable number of such hernias and to call attention to their frequency and symptoms. These small hernias are difficult to demonstrate in a roentgenogram. For the study of these cases the fluorescent screen is the method of choice. They usually occur through one of the normal openings, especially the esophageal hiatus. The elevation of the diaphragm is only moderate and is best seen after the patient has ingested an opaque meal. Healy stresses the fact that the esophageal opening is the only opening that is muscular in structure, therefore amenable to dilatation. The aortic opening has never been known to contain a hernia, he states, first, because this opening is anatomically a development not of the diaphragm but behind it; second, its origin is tedinous, not muscular, and attached closely to the vertebræ by the crura. In spite of the fact that the foramen of Morgagni and the quadrilateral space situated laterally are supposed to be the weakest areas in the diaphragm, all of the hernias seen by Morrison and Healy were at the esophageal opening, and generally behind the esophagus. They varied in size, the smaller ones about the size of an English walnut and the larger ones as large as a grapefruit. While watching the opaque meal under the fluoroscope, the hernia will be seen to fill first and later the esophagus.

This type of diaphragmatic hernia is readily demonstrated if the cardia is filled with an opaque medium and pressure put on the diaphragm either by the patient taking a full breath and holding it or by placing the patient in the Trendelenburg position. With the patient supine and rotated in the left oblique position so as to get an oblique view under the fluoroscope, the fundus portion of the stomach will seem to pass above the diaphragm. Shortly after this, the esophagus will fill. Occasionally, the right oblique supine or prone position gives better results.

The great difficulty in diagnosing the small hernia is that, as soon as the cardia begins to empty, there is a spontaneous reduction. This makes it quite difficult at times to get a film, several examinations often being necessary.

The symptoms of this type of diaphragmatic hernia present the widest variations, from vague discomfort to findings similar to those in gall-bladder disease or ulcer. Many patients have regurgitation in the morning, with hyperacidity, if they have been sleeping on their backs. This is explained by the cardio-esophageal opening being incompetent. A few have difficulty at times in swallowing solid food. This is probably due to kinking of the esophagus, which is pulled up by the hernia, or to the herniated and filled fundus causing pressure. Some say they are unable to lie down after a full meal as it has been found to cause gastric distress, dyspnea, and palpitation. One or two patients had spells of vomiting. The discomfort did not appear to depend on the size of the hernia but on its being adherent or blocking the esophagus. Many of these patients have been operated on successfully, with relief of symptoms.

Diaphragmatic hernia impairs health and in most cases incapacitates the patient. In a large proportion of the cases (33 1/3 per cent) studied by Hedblom, there was strangulation. Operation after obstruction doubles the post-operative mortality.

It would appear that roentgen diagnosis in the conditions considered should hold a high place when arrived at by proper roentgen methods.

REFERENCES

(1) WILLIAMS, FRANCIS H.: Roentgen Rays in Medicine and Surgery. Macmillan Company, New York, 1903.
(2) PANCOAST, HENRY K.: The Roentgenological Diagnosis of Liver Abscess. Am. Jour. Roentgenol. and Rad. Ther., October, 1926, XVI, 303.
(3) LOCKWOOD: Subphrenic Abscess. Surg., Gynec. and Obst., 1921, XXXIII, 502.
(4) NORRIS and LANDIS: Diseases of the Chest, 1917, p. 596.
(5) BOYD: Surgical Pathology, 1925.
(6) WESSLER and JACQUES: Clinical Roentgenology of Diseases of the Chest. Southworth Company, 1923.
(7) STEWART, W. H., and STEIN, A. W.: Roentgen-ray Study of the Abdominal Organs Following Oxygen Inflation of the Peritoneal Cavity. Am. Jour. Roentgenol. and Rad. Ther., November, 1919, VI, 533.
(8) SOMMER, J.: Die Rontgenunterschung des subphrenischen Abszesses sur Foststellung des operationsplane (The Roentgen-ray Examination of Subphrenic Abscess in Establishing the Plane of Operation). Zentralbl. f. chir., 1923, L, 215.
(9) FIFIELD, LIONEL, and LOVE, R. J. MCNEIL: Subphrenic Abscess. Brit. Jour. Surg., 1925, XIII, 683.
(10) HEDBLOM, CARL A.: Diaphragmatic Hernia—A Study of 375 Cases in Which Operation was Performed. Jour. Am. Med. Assn., Sept. 26, 1925, LXXXV, 947.
(11) RICHARDS, L. G.: Ann. Otol., Rhinol., and Laryngol., December, 1923, XXXII, 1145.
(12) MORISON, J. M. W.: Arch. Radiol. and Electrother., September, 1923, XXVIII, III.
(13) MORRISON, L. B.: Diaphragmatic Hernia of Fundus of Stomach through Esophageal Hiatus. Jour. Am. Med. Assn., Jan. 17, 1925, LXXXIV, 161.

DISCUSSION

DR. E. H. SKINNER (Kansas City): That is an excellent outline of the position of the diaphragm in relation to the pathology above and below this muscle. Just as Dr. O'Brien stated in his opening remarks, we are particularly interested in the definite information which can be obtained through the X-ray in cases of subphrenic abscess. In this acute condition the information which the radiologist is able to afford the physician is important. The radiologic syndrome obtained in subphrenic abscess is usually seen in the hospitalized patient who has had an abdominal operation. It consists of an elevation, usually of the right diaphragm, a fixation of the diaphragm, a perpetuation of the normal aeration of the costophrenic and the cardio-phrenic angles. Undoubtedly we sometimes are too timid in asserting ourselves upon the value of these shadows.

STUDIES IN THE DYNAMICS OF HISTOGENESIS

XIII. The Clinical Application of the Dynamics of Histogenesis, Regarding the Origin, Growth, and Structural Maintenance of Patellar Bone, Knee Joint, and Related Thigh Muscles Mobilization and the Traction Trabeculæ and Pressure Pillars of Human Patellæ

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THE active dynamics determining the origin of bone were determined embryologically by the writer (1919-20-21-22) and experimentally for patellar bone by the writer and his co-workers (1927)[1] by the following means: Three sets of experiments were performed, beginning in 1922, and continued up to date (1927). (1) Thirty-nine dogs: The patellæ of dogs were excised and the tendons of the quadriceps extensor femoris muscles were sutured to the patellar ligaments. The knee joints were left intact. (2) Three dogs: The patellæ were excised. The knee joints were ankylosed by removal of the articular cartilages and fixation of the femora to the tibiæ, with wire. The tendons of the quadriceps extensor femoris muscles and the patellar ligaments were sutured together. (3) Four dogs: The patellæ were left intact and the knee joints ankylosed, as described above.

THE ORIGIN OF PATELLAR BONE

The conclusions derived from the evidence resulting from the above experiments were the following: (1) Under adequate mechanical conditions produced by an intact, normally mobile knee joint and its related soft parts, patellar cartilage and bone regenerate after the patella is excised from young connective tissue cells which had not been destined as specific formers of bone. (2) When adequate mechanical conditions are altered by means of immobilizing the knee joint (arthrodesis), with the patellæ left intact, patellar cartilage and bone atrophy. (3) When the patella is excised *in toto* and adequate mechanical conditions are altered by means of knee joint fixation, patellar cartilage and bone do not regenerate, even with the tendon of the quadriceps extensor femoris muscle and the patellar ligament united by suture. (4) The "adequate mechanical conditions" are a normally mobile, exercising articulation with the soft parts replaced, a condition met in the case of a knee joint where the patella is excised and the tendon of the quadriceps extensor femoris muscle sutured to the patellar ligament with quickly absorbable material.

The patellar bone, therefore, is dependent in origin and structure. It is neither self-made nor self-supporting. Its genesis and continued existence in actuality are contingent upon the mobility of the knee joint and the pressure and tension, of a remittent character, produced by the activity of the quadriceps extensor muscle through its tendon that passes over the ventral aspect of the lower end of the femur.

The origin of intratendinous zones of ossification, such as the patella, and known as the sesamoid bones, is due to an adequate degree of intermittent or remittent traction and pressure induced as osteogenetic stresses in a tendon where it repeatedly bends over a bony surface of a movable joint like

[1] The results of these experiments were presented in a paper read before the Association of American Anatomists, April, 1927, at Nashville, Tennessee.

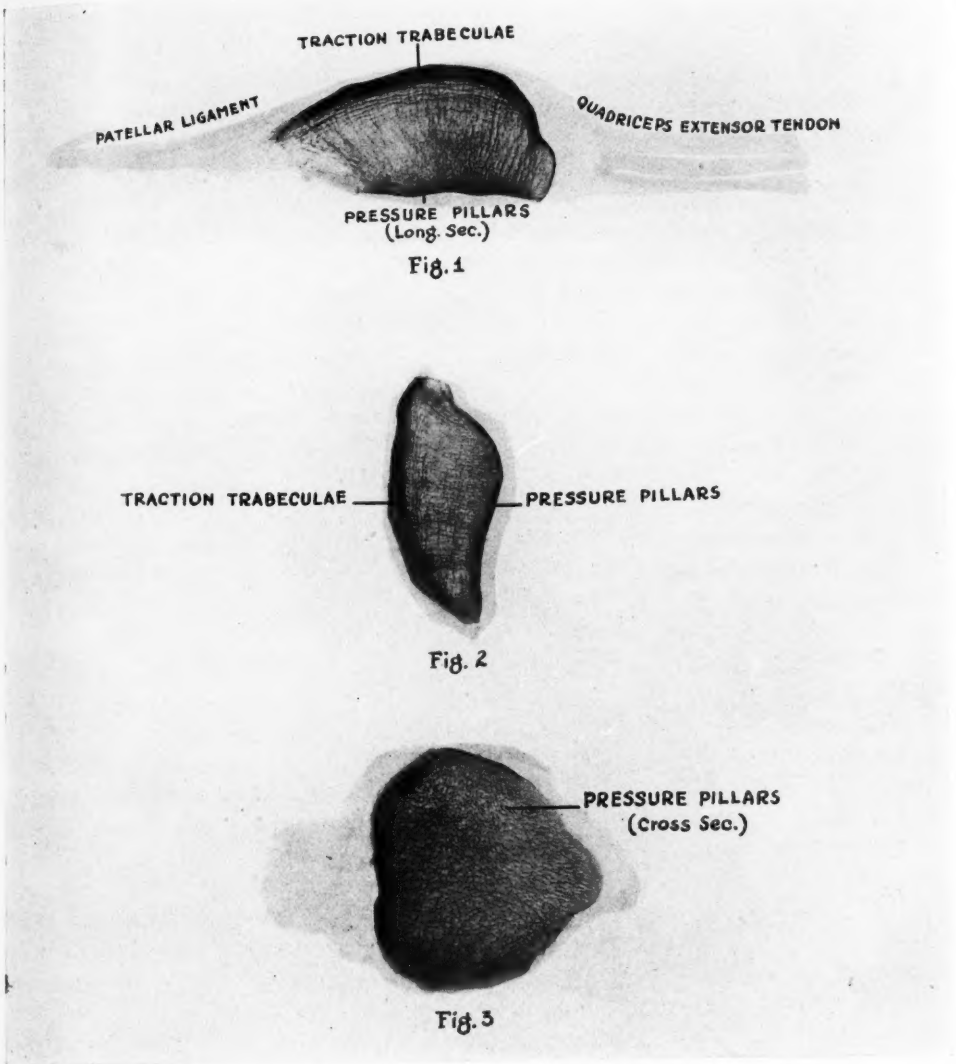

Plate I. Fig. 1. Roentgenogram of human patella (mid-sagittal section). The traction trabeculæ are on the ventral aspect of the patella in the direct line of traction of the tendon of the quadriceps extensor muscle and the patellar ligament. The pressure pillars are arranged at right-angles to the traction trabeculæ and converge toward the dorsal or articular aspect of the patella. The articular cartilage is evident by its lighter-shadow-casting property (natural size).

Fig. 2. Roentgenogram of human patella (cross-section). The arrangement of the pressure pillars at right-angles to the traction trabeculæ is clearly evident in this section (natural size).

Fig. 3. Roentgenogram of human patella (coronal section). The pressure pillars, or columns, are cut in cross-section (natural size).

the rope of a pulley. Tension is produced by a pull on the tendon by the muscle and pressure by the compression of the tendon where it bends over a bony surface of a movable joint. The tension or traction trabeculæ and pressure pillars of the human patella are evident in Plate I.

Gillette (1872) states that the intratendinous bones are due to the physiological irritation which results from the incessant friction of some tendons on the bones. Lunghetti (1905) writes that these ossicles are segments of tendons specially modified by the action of a mechanical agent. Therefore, the same cause in the origin of the intratendinous sesamoid bones is given to muscular osteomata or ossifying myositis. The macroscopic and microscopic morphology does not separate the group.

Gillette records that sesamoid bones have the internal structure of short bones. They consist of cancellous tissue covered by a thin layer of compact tissue. In the adult this cancellous tissue may be very dense. The osteomata may be formed of cancellous tissue covered by compact tissue or may be completely compact; they may have haversian canals.

Lima (1913) does not consider that friction is a sufficient cause to determine the appearance of the intratendinous bones. If these ossicles have such an origin, they should be commoner. He states that the tendon of the long head of the biceps brachii has a situation and bone relationship resembling the tendon of the peroneus longus, nevertheless was a sesamoid bone ever found in the tendon of the long head of the biceps, whereas the sesamoid bone in the tendon of the peroneus longus is the most constant.

There is, however, a different relationship of pressure to bone in the tendon of the peroneus longus than in the biceps brachii. The tension and pressure are distributed over a greater extent in the tendon of the biceps humerii than in the tendon of the peroneus longus. In other words, a more limited extent of tendon of the peroneus longus is subjected to the adequate pressure stimulus to form bone than in that of the biceps brachii.

Parsons (1905) concludes that sesamoid bones are traction epiphyses, and into them the tendons are inserted. The articular or pressure epiphyses are at the ends of long bones, and by them pressure is transmitted from bone to bone.

For the first time, the experimental evidence is presented in the results recorded above, that the intratendinous patella is a resultant of muscular activity and knee-joint mobility. Intermittent or remittent traction is produced by muscular pull upon the reacting tendon, and pressure is induced into the tendon where it bends over the ventral aspect of the lower end of the femur to its attachment on the tuberosity of the tibia.

THE CLINICAL USE OF PHYSICAL AGENTS IN BONE REPAIR

The bony and muscular systems of the body are interdependent in origin and maintenance of structure. The normal mobility of the joints is intrinsically related with the interaction of bone and muscle. Embryological evidence has been presented by the writer (1919-20-21-22) showing the interrelationship of bone, muscle, and joints during their genesis and growth.

A closely graded series of hind limbs of pigs, ranging from 10 to 100 mm., were serially sectioned and studied (See Plates

2Abbreviations (Plate VI): *d.p.m.*, dorsal pre-muscle mass; *v.p.m.*, ventral pre-muscle mass; *a.*, acetabulum; *il.*, ilium; *is.*, ischium; *s.n.*, sciatic nerve; *f.*, femur; *f.n.*, femoral nerve; *1*, rectus femoris muscle; *2*, vastus intermedius muscle; *3*, tensile perichondrial strain fibrosis (periosteum); *4*, osteogenetic tissue; *5*, tensile osseous trabecula; *6*, degenerating cartilage cells arranged along tensile and compressive stress lines; *7*, proliferating cartilage cells in advance of degenerating zone; *8*, abductor magnus muscle; *9*, pyriformis muscle; *10*, semimembranous muscle; *11*, compressive osseous trabecula; *12*, compressive perichondrial strain fibrosis (periosteum); *dorsal angle*, angle formed by a line through the dorsal aspect of the longitudinal axis of the limb with a dorsoventral line through the center of hip joint; *pre-axial angle*, angle formed by pre-axial aspect of limb with lateral body wall. By reference to the various changes in these angles the rotation of the hind limb is exemplified on a plane

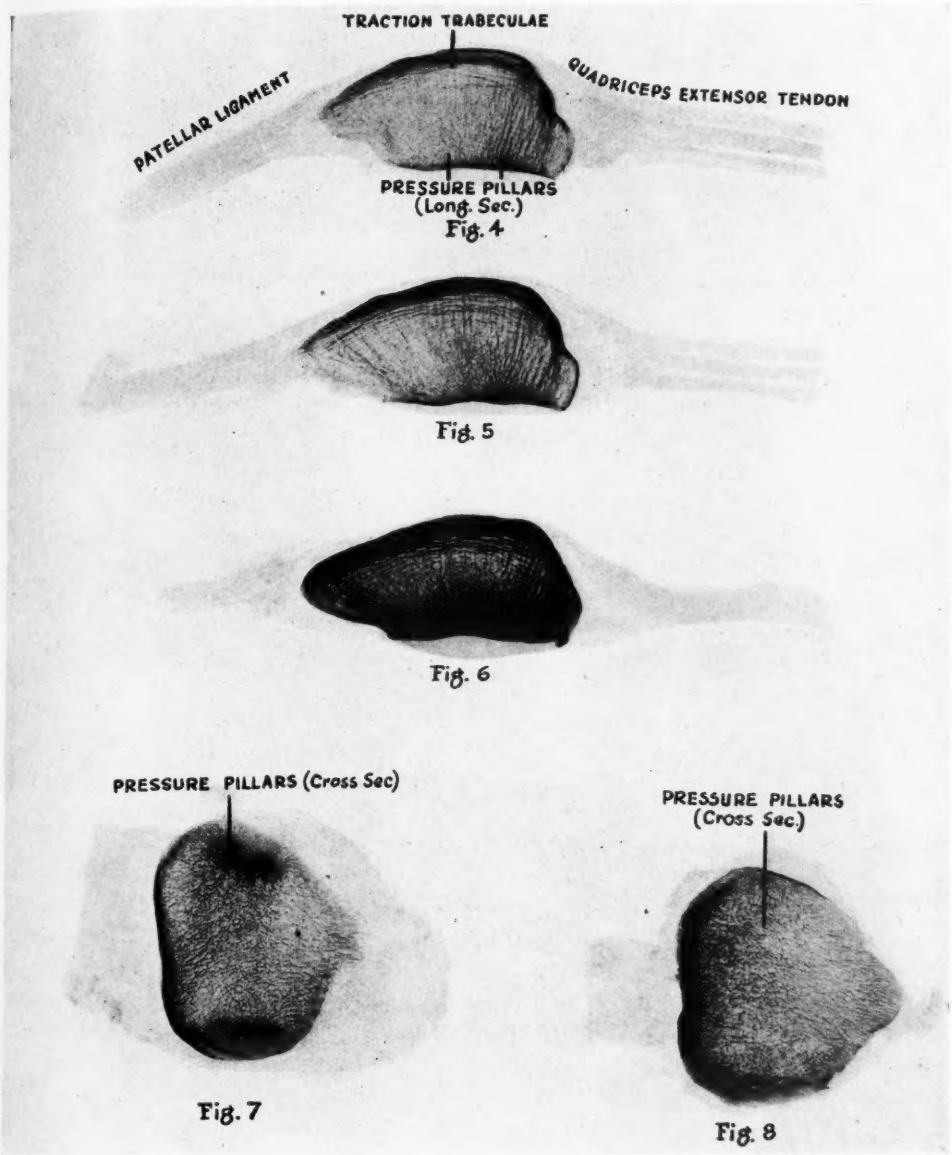

Plate II. Figs. 4, 5, and 6. Roentgenograms of human patellæ, mid-sagittal sections 1 mm. thick. These mid-sagittal sections are of different human patellæ, showing the similar arrangements of the traction trabeculæ and pressure pillars in this plane of section (natural size).

Figs. 7 and 8. Roentgenograms of human patellæ, coronal sections 1 mm. thick. The circular and oblong centers of the pressure pillars, or columns, cut in cross-section are clearly evident (natural size).

surface. Since the aspect of the limb cannot change in these figures, the body axis is represented as changing.

The attention of the observer is specifically directed to the following facts:

1. The volume of the central condensed blastemal skeleton (Fig. 2) occupies relatively more space of the thigh than the femur in Figures 4, 5, 6, and 7. It is immediately evident that as development advances the relative volume of the femur to thigh decreases. At the same time, the density increases as exemplified by the progressive deposition of bone (Figs. 6 and 7, Nos. 5 and 11). The bone on the convex side is drawn out in tension, that on the concave side is compressed. The first deposition of bone, therefore, follows the mechanical laws.

2. The width of the femoral segment is relatively greater in Figure 2 than that in Figures 4, 5, 6, and 7. The femur grows relatively more rapidly in length than in width in embryos 14 to 25 mm. in length. Note that during the accel-

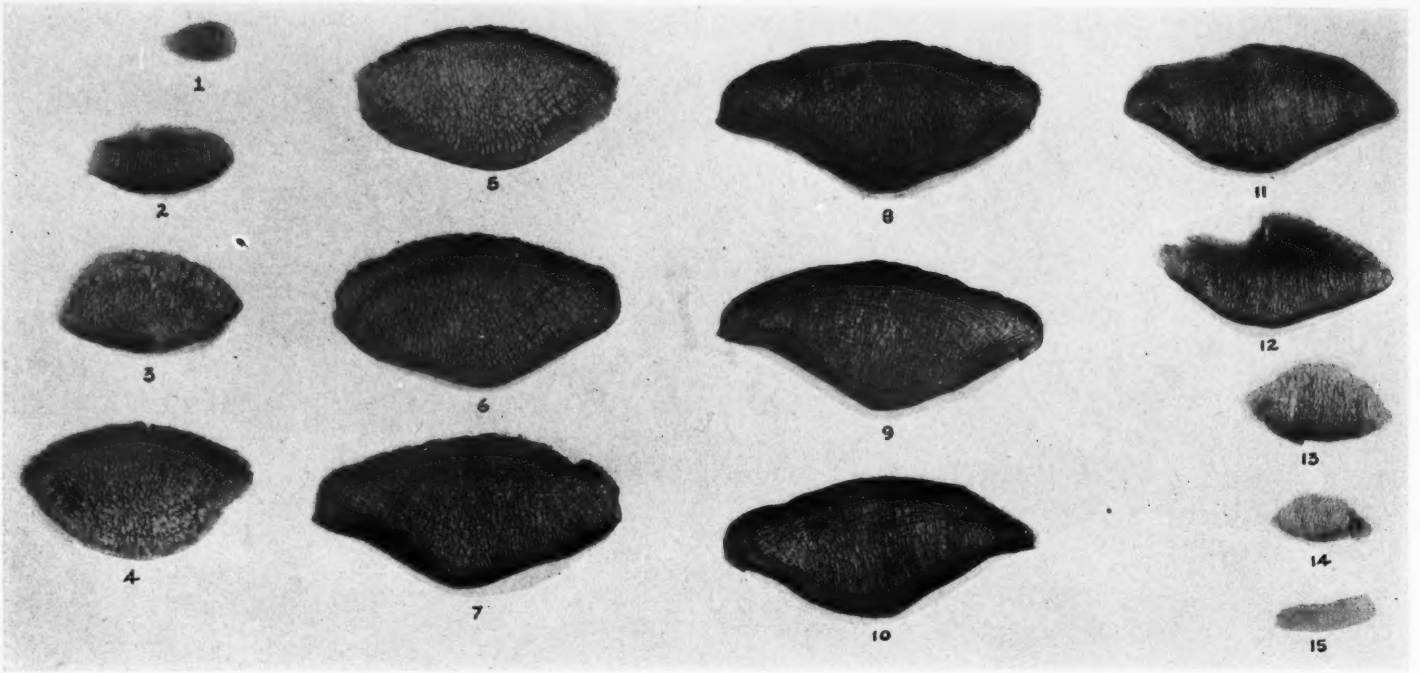

Plate III. Figs. 1 to 15. Roentgenograms of a single human patella, cut in serial cross-section, each section 1 mm. thick. Figure 1 is the cephalic end of the series and Figure 15 the caudal member of the series. The right angular arrangement of the traction trabeculæ and the pressure pillars is clearly evident (natural size).

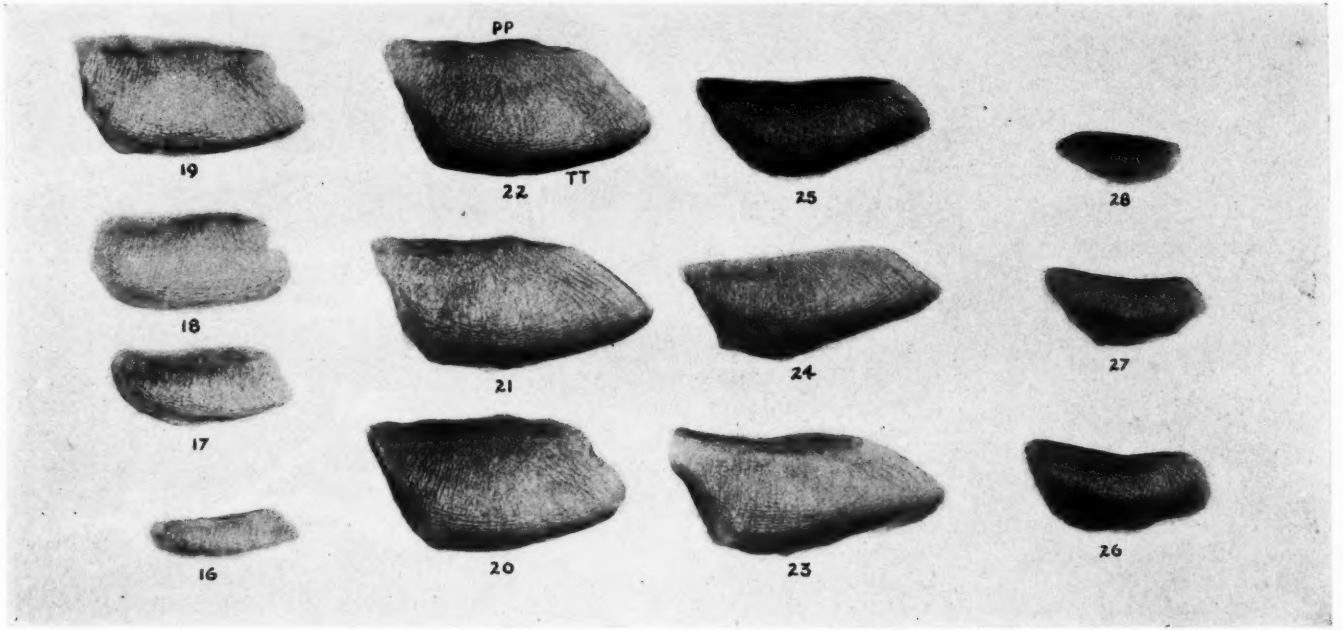

Plate IV. Figs. 16 to 28. Roentgenograms of a single human patella, cut in serial sagittal sections, each section 1 mm. thick. Figure 16 is the medial end of the series and Figure 28, the lateral member of the series. "PP" is at the articular aspect of the patella toward which the pressure pillars converge. "TT" is at the ventral aspect of the patella where the compact traction trabeculæ are placed (natural size).

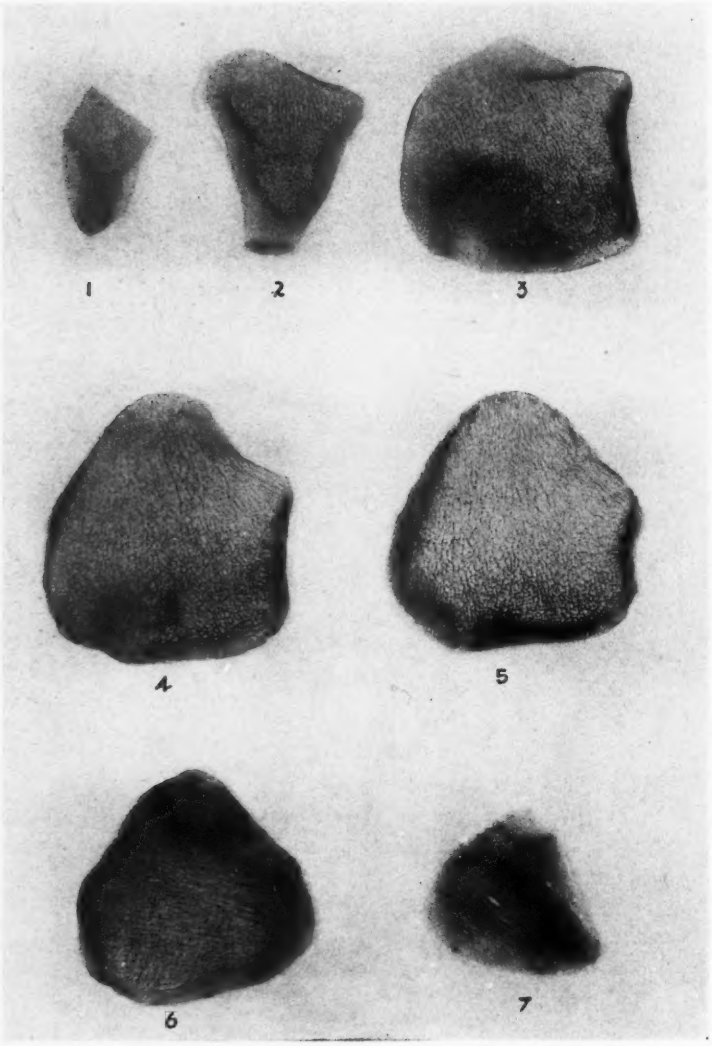

Plate V. Figs. 1 to 7. Roentgenograms of a single human patella, cut in serial coronal sections, section 1 mm. thick. Figure 1 is the dorsal or articular member of the series and Figure 7, the ventral member of the series. Figure 7 is composed primarily of the compact longitudinal traction trabeculæ. Figure 4, through the center of the patella, is composed of pressure pillars cut in cross-section (natural size).

erated longitudinal growth of the femur the progressive appearance of more and more definite traction lines is seen in the surrounding mesenchyme retarded in longitudinal growth. Along these lines the fasciculi of the developing muscles form, due to the tension of differential longitudinal growth. The determination of accelerated and retarded growth is based on the number of mitotic figures and the compactness of the nuclei per square millimeter of cross-section in a field of differential growth.

3. The force of longitudinal growth of the femur is from ten to fifteen times greater than that of the acetabulum. Compare along the line labeled "limb axis." Note, at the same time, the inevitable mechanical effects of muscular pull. These factors, together with the strengthening influence of femoral ossification, determine the location of the convex ball of the hip, ball-and-socket joint, on the femur and not on the region of the acetabulum.

4. The tensile perichondrial strain fibrosis is clearly detected as a limiting membrane, first appearing on the convex aspect of the bent femur (Figs. 3, 4, 5, 6, 7, No. 3). Figure 4 represents the limb of a living embryo injected with India ink. Note that the injected capillaries are outside of the perichondrium. This membrane strangles the cartilage cells at the center of the bent femur and later becomes modified into the periosteum from which the osteoblasts proliferate. The osteoblasts, by appositional growth, replace the degenerating cartilage scaffold with a more rigid bony base. These cellular reactions are elicited by the progressive in-

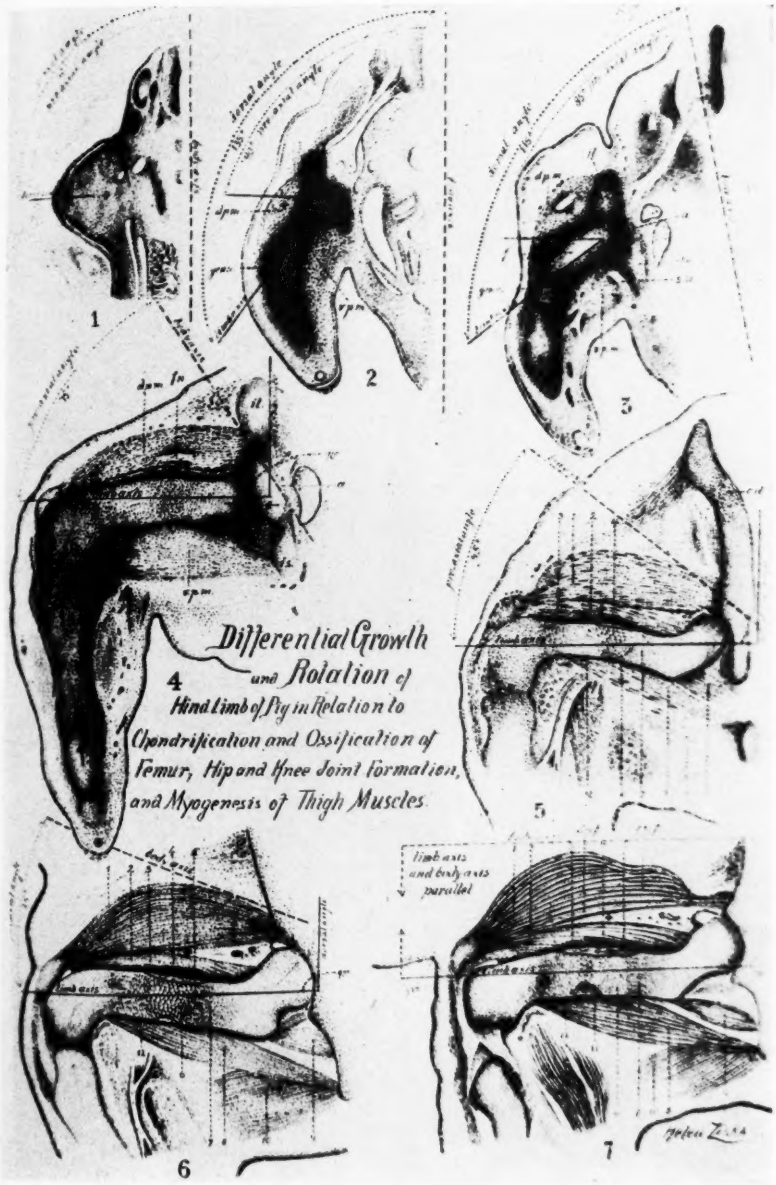

Plate VI.—Explanation of figures (after Carey, Am. Jour. Anat., 1921, XXIX, No. 1).

1. Middorsoventral, longitudinal section of hind limb bud of a pig embryo 10 mm. in length. (×40)
2. Middorsoventral, longitudinal section of hind limb bud of a pig embryo 12 mm. in length. (×40)
3. Middorsoventral, longitudinal section of hind limb bud of a pig embryo 14 mm. in length. (×40)
4. Middorsoventral, longitudinal section of hind limb bud of a pig embryo 16 mm. in length.
5. Middorsoventral, longitudinal section of the thigh of a pig embryo 20 mm. in length. (×40)
6. Middorsoventral, longitudinal section of the thigh of a pig embryo 25 mm. in length. (×40)
7. Middorsoventral, longitudinal section of the thigh of a pig embryo 29 mm. in length. (×40)

VI and VII and Footnotes 2 and 3, on pages 236, 237, 240, 242.) This microscopic study, although purely descriptive morphology, at least revealed the histologic steps in the development of joints, cartilage, bone, and muscle of the limb as a whole. It aided in revealing the active processes of resistance as a factor in chondrogenesis and osteogenesis in sequence, and suggested the experiments of this study. The resistances to the growth of the skeletal elements were regarded as follows: (1) opposed growth of contiguous accelerated growing skeletal segments; (2) weight of related soft parts; (3) reactive elasticity of traction of the soft parts retarded in growth; (4) active muscular pull by embryonic muscles on first the cartilaginous and later the bony levers.

Since there is an interdependency in the origin, growth, external form, and internal structure of bone, muscle, and joints, any change from this normal relationship, such as a fracture, involves more than the simple structural repair of the broken bone. The index of the success or failure in the treatment of fracture is estimated in terms of joint, muscle, and bone functional restoration. According to Page and Bristow (1923) it is perhaps hardly necessary nowadays to condemn the practice of "setting the fracture" and immobilizing the limb in splints until union is firm without treating the muscle and joints. It will be but little satisfaction to the patient to be told that his fracture is "cured," if he finds himself with a stiff, painful, and useless limb as a result.

The treatment of fractures by the methods of massage and mobilization (passive, active, forced movements, exercises, and electrical treatment) introduced by Lucas-Championniere (1879), and later advocated by Hey Groves and Robert Jones, yields excellent results in the hands of the trained expert. Page and Bristow state that this method requires special training and expenditure of much time and is, therefore, not applicable for the routine treatment of fractures in general practice. In the hands of those not expert the method may lead to disaster. Indications as to the time when movement should be commenced and splints discarded is dependent upon the type of fracture and the bone involved.

The logical method of massage and mobilization carried out at the right time in the treatment of fractures, such as chewing gum in jaw fractures, is supported by the experimental evidence on the regeneration, failure of appearance, and atrophy of the patellæ under the conditions of the experiments cited above. This is added evidence under controlled conditions, in addition to publications by others, to the clinical evidence of fracture treatment, of the wisdom of early massage and mobilization (ambulatory splints). The early use of elastic bands in the treatment of ischemic palsy and nerve lesions has a scientific foundation in fact in the prevention of deformities by the normal balancing of synergistic and antagonistic groups of muscle.

Since the application of the facts of embryology and experimental surgery sustain the thesis that there is a dynamic as well as a static interdependency and interactivity of bone, muscle, and joints, and that this requires special knowledge in the treatment of fractures, it behooves the general prac-

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tensity of the strain to which the femur is subjected by the resistances to advancing femoral extension. Longitudinal femoral accelerated growth and extrinsic resistances to this growth are interactions that must be intensively studied in order to appreciate the competition and the resultant products of differential growth.

[2]Abbreviations (Plate VII): *m.*, mesenchyme; *ecto.*, ectoderm; *il.*, blastemal ilium; *is.*, blastemal ischium; *d.p.m.*, dorsal pre-muscle mass; *v.p.m.*, ventral pre-muscle mass; *b.f.*, blastemal femur; *b.t.*, blastemal tibia; *il.*, ilium; *is.*, ischium; *r.*, rectus femoris; *a.*, acetabulum; *h.*, head of femur; *g.t.*, greater trochanter; *l.c.*, intermediate growing cartilage; *t.o.l.*, tensile osseous lamella; *c.o.l.*, compressile osseous lamella; *t.p.*, tensile periosteum (chondrium); *c.p.*, compressile periosteum (chondrium); *v.i.*, vastus intermedius muscle; *a.m.*, adductor magnus muscle; *p.*, patella; *l.p.*, ligamentum patellæ; *f.*, femur; *t.*, tibia.

N. B.—The most actively growing region of the thigh *per mm.* cross-section is the skeleton. This growth tends to draw out in tension the less actively growing mesenchyme, which results in the elongation forming the ventral and dorsal pre-muscle masses (*d.p.m.* and *v.p.m.*, Plate VII, Figure 16). With increasing tension due to skeletal growth the individual definitive muscles are formed. Concomitant with muscle formation, skeletal condensation is seen progressively through the blastemal, cartilaginous, and osseous stages.

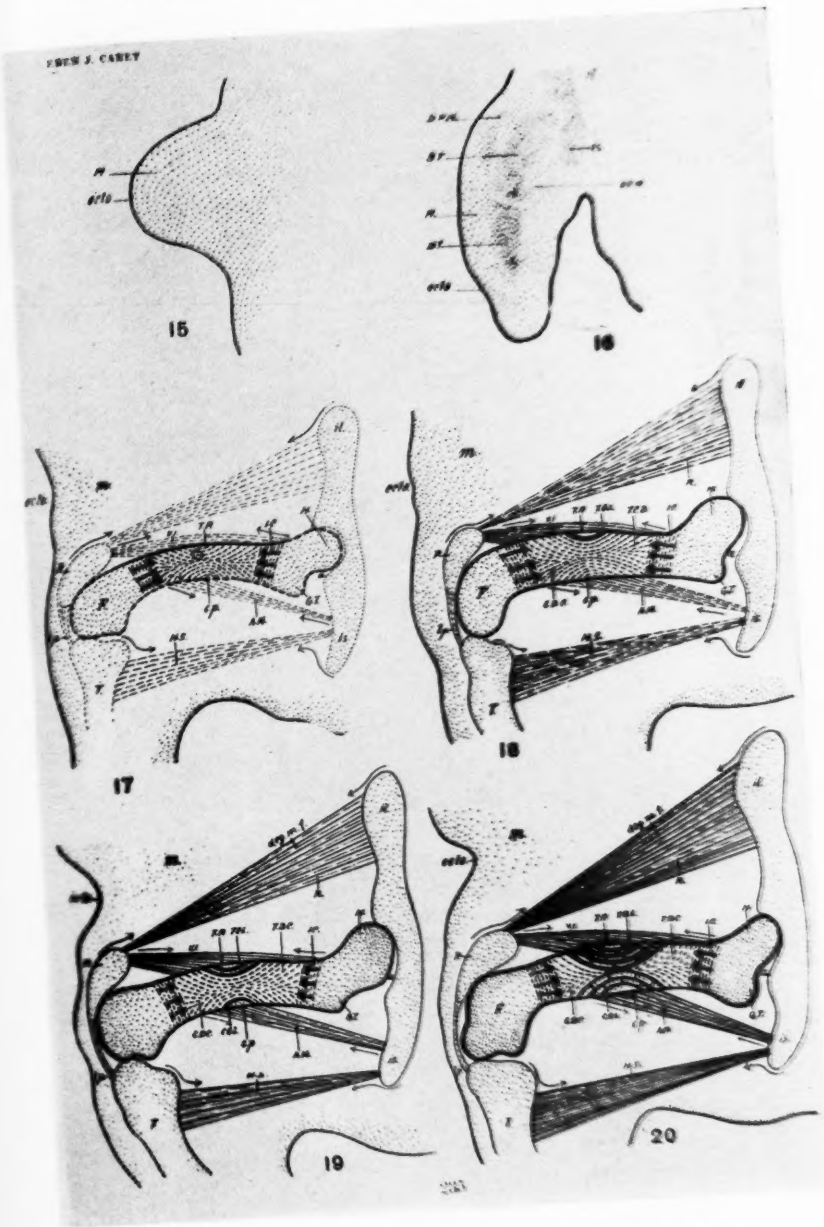

Plate VII.—Explanation of figures (after Carey, Anat. Record, 1920, XIX, No. 4).

15. Dorsoventral section through hind limb of 10-mm. embryo pig.
16. Dorsoventral section through hind limb of 14-mm. embryo pig.

Schema of bone and muscle origin of thigh: 17. Dorsoventral section through hind limb of 18-mm. embryo pig. Stage of cartilaginous femur. 18. Dorsoventral section through hind limb of 25-mm. embryo pig. Stage of inception of osseous femur. Bone formation beginning on tensile aspect of bent cartilaginous femur (*t. o. l.*). 19. Dorsoventral section through hind leg of 32-mm. embryo pig. 20. Dorsoventral section through hind limb of 50-mm. embryo pig.

titioner to regard fractures not just as broken bones, but as internal derangements of the limb as a whole. The origin, maturity, and repair of bone, muscle, and joints must be considered as an interacting, interdependent, triple system. This statement is based on the experimental evidence supplied by the patella and applied to the skeleton in general from the facts of embryology, presented in the following conclusions: Patellar bone is dependent in origin, being neither self-made nor self-supporting; its existence is contingent on the integrity of the limb as a whole, on the mobility of the knee joint, and the pressure and tension induced by the activity of the quadriceps extensor femoris muscle on its tendon that passes over the ventral aspect of the lower end of the femur.

In the treatment of fractures, therefore, the broken bone and its related muscles and joints are intimately involved in the restoration of function. There was a dynamic interaction of the parts forming the limb (mobilization), displayed in intra-uterine life, transforming bone, muscle, and joints from the potential to the actual state. The functional interactivity, replacing differential growth (accelerated longitudinal growth of skeleton and relatively retarded long growth of soft parts) in the mature state, is one of the sustaining influences maintaining the normal external form and internal structure of bones, muscles, and joints in the adult. No integer of this triumvirate may be displaced or fixed without affecting the other two. It was a logical therapeutic step, therefore, that the principle of early massage and mobility (passive and active) under expert guidance, was introduced in the treatment of fractures.

Speed (Fractures and Dislocations, 1916, p. 136) states that the effect of the healing of fractures by mobilization is the functional use and consequent activity of normal healthful processes. This is a clinical expression or interpretation of the facts of embryology stated above. It is the logical dynamic functional, in contrast to the static structural, viewpoint of certain general practitioners in the treatment of fractures. Some may have been led astray by those otherwise logical lectures of Hilton's on Rest and Pain (1872), by too long attempts at relative rest and immobilization.

Clinicians came to the realization that bones, muscles, and joints are maintained by functional mobility, by means of empiricism, by the long trail of "trial and error." The anatomists and pathologists were unable to add to the quicker realization of the value of mobility and functional interactivity of bones, muscles, and joints because the majority regard these structures as independent and unrelated in origin in the embryo, which they are not. The difference between the conditions of bones, muscles, and joints during pre- and post-natal life is purely one of degree, not an essential difference in kind, as regards the induced stresses leading to the origination of these parts.

In the embryo the differential growth of the limb, manifesting longitudinal acceleration in the skeleton (scleroblastema, cartilaginous and osseous) and relative retardation of the soft parts, together with the initial segmentation of the primitive scleroblastemal skeleton, is sufficient to explain the origin and completion of growth of bones, muscles, and joints, providing nutritional and nervous conditions are adequate. When growth ceases the intermittent or remittent pressure, tension, and friction produced by active functional movements are comparable to but greater in degree than that induced by the interacting movements of differential growth and frictional segmentation of the primitive gelatinous skeleton base. The embryologic and experimental evidence of the value of mobility has long trailed the clinical application of this principle by the best surgeons,

because anatomists and pathologists have had a static, rather than a dynamic, viewpoint of histogenesis of bone, muscle, and joints, not only during normal growth but during the process of repair following injury. A nebulous notion is held that these tissues just grow, like the one held by Topsy in regard to her own origin—"Jus' grow'd."

THE TRACTION TRABECULÆ AND PRESSURE PILLARS OF THE HUMAN PATELLA

In 1922 the writer published observations on the internal structure of the femur in the pig and in man. The following question was asked and the tentative answer was given:

Why does the pig's femur continue to differentiate the laminar type of bone with more or less concentric rings like those of a tree, on its ventral and side walls, whereas, the human femur, which resembles the internal structure of the pig's femur at the time of birth, differentiates, after the child begins to walk, into the haversian type of bone?

This question may be answered as follows: The femur is primarily subjected to compressive stresses in sustaining body weight in the erect condition, whereas, the pig's femur is primarily subjected to tensile stresses due to muscular traction, except on its dorsocephalic wall, which is concave, and haversian canals or *pressure pillars* are found. Here compression predominates. The pig's femur in the natural articulated condition forms an angle of about 45 degrees with a vertical line through the center of the acetabulum. As a consequence, the weight of the hind quarters is primarily sustained by the large thigh muscles, which use the femur for leverage. There is proportionately more muscle attached to bone in the pig's femur than in man's; the human femur being more erect is in direct line to sustain body weight. The stresses in the human femur are, therefore, predominantly compressive. In the pig's femur the stresses are predominantly tensile, due to muscular pull. It may be taken as axiomatic that muscles act primarily in tension upon the bones to which they are attached.

As regards the laminar and haversian types of bone, the following conclusion may be drawn: Laminar bone is differentiated wherever the predominant stresses are tensile, whereas the haversian type of bone is differentiated wherever the predominant stresses are compressive.

It may be emphasized, furthermore, that the stresses in the human femur are predominantly compressive rather than tensile. This is the result of the fact that the direct sustaining action of body weight and related di-arthroidal muscles is greater than the traction action of the attached thigh musculature (mono-arthroidal). The type of bone, therefore, which is elicited in response to compressive stresses is laid down after birth progressively in the human femur with the gradual assumption of the erect position and increasing use of the femur in sustaining body weight.

The femur of the pig is used not only to sustain body weight, but to afford leverage for the massive musculature; therefore, the primary stresses elicited are tensile. This is due to the fact that the great muscles of the hind quarters, which use the femur for leverage, induce greater tensile stresses in the femur than the compressive stresses induced by body weight. The type of bone, therefore, which is elicited in response to tensile stresses, is laid down progressively in the pig's femur with the increase in the cross-sectional area of the thigh musculature; the internal structure of the diaphysis of this bone is of the laminar type on its convex dorsal and side walls.

A search was made in sections of the various bones of the human skeleton to find, if it were possible, a laminar or traction

trabecular type of bone, that would be more or less definitely related to traction, tension, or muscle pull. Thin plates of the patellæ of the human in a sagittal plane were ground down on emery paper and a more or less pure type of traction trabeculæ distinct from pressure pillars comparable to the tension laminæ of the pig's femur was found. The object of this part of the paper is to record the roentgen findings of the internal structure of the patella, revealed by a study of thin plates of the human patella, 1 mm. thick, in various planes of section. Some of the sections were ground to microscopic thinness for histologic study.

J. Gillette (1872) stated that the sesamoid bones in general have the structure of the short bones; they consist of cancellous or areolar tissue, covered by a thin layer of compact tissue. Neither the arrangement, function, nor direction of the cancellous and compact tissue of sesamoid bones was revealed, especially as regards the striking pattern of the patella herein illustrated and described. Meyer (1869) and Jansen (1920) describe the arrangement of the trabeculæ, but the characteristic internal structure of the various planes of section through the human patella in its entirety was not revealed.

During the extension movement in the knee, from each point of the articular surface of the patella which successively comes in contact with the femoral condyles, a series of pressure lines radiate approximately in the shape of a fan or the spokes of a wheel, which have to be represented by bone elements. When, from a series of points of the outline of the ventrodorsad section of the patella, such fan-shaped radiating lines are drawn, they appear to cross in certain places. With an increase in number of these radiations, they will occupy nearly the whole area, leaving apertures between them which are small and approximately circular near the articular surface and larger and more nearly oval in the distance.

The pressure pillars of the patella are arranged somewhat in the manner found for the cancellous tissue in the femoral condyles by Murk Jansen (1920). The pressure pillars have a preference in the arrangement of their elements for the direction in which the pressure stresses of their elements are strongest, so that they can schematically be considered to be composed of numerous bone plates running dorsoventrally from the articular surface behind to the dorsal surface of the traction trabeculæ in front. From the lateral aspect these bone plates have apertures which are small and round near the articular surface and become larger and more oval the farther away they are from it. The trophic influence of the pressure stresses is unquestionably the stimulus in the formation of the pressure pillars, and the muscle action of the quadriceps extensor femoris appears to be the cause of this pressure.

The traction trabeculæ are in the direction of greatest tension and their development and lineation are due to the action of tension stresses produced by the pull of the quadriceps extensor femoris muscle through its tendon. This is continuous with the periosteum on the ventral aspect of the patella.

Three planes of sections of human patellæ were studied, as follows:

1.—Mid-sagittal longitudinal sections, 1 mm. thick of 60 human patellæ. The planes of section through the mid-sagittal lines of the patellæ, including the quadriceps extensor tendons and the patellar ligaments, reveal two arrangements of the bony trabeculæ. First, on the ventral, non-articular aspects there are from fifteen to thirty plates of *laminar* bone, in the direction of the quadriceps extensor femoris muscle and the patellar ligament. Second, at right angles to the laminar bone there are directed dense cancellous trabeculæ or pillars, whose

long axes correspond to the transverse diameter of the patella ventrodorsad. These cancellous bony trabeculæ have a tendency to converge toward, or radiate away from, the cartilaginous articular aspects of the patellæ (Plates I and IV).

2.—Mid-transverse sections, 1 mm. thick, of 60 human patellæ. The planes of sections through the mid-transverse lines of the patellæ reveal the double arrangement of the bony trabeculæ noted in the mid-sagittal planes. First, on the ventral aspects there are found the fifteen to thirty tension laminæ, and in the second group, at right-angles to these, the compression cancellous trabeculæ (Plates I and III).

3.—Mid-coronal sections, 1 mm. thick, of 60 human patellæ. These planes of the sections lie dorsal to, therefore do not cut through, the tension *laminar* bone on the ventral aspects of the patellæ. The network of the pressure trabeculæ of the columns, or pillars, is clearly observed as oblong or rounded structures in cross-section (Plates I, II, and V).

CLINICAL SIGNIFICANCE OF THE INTERNAL STRUCTURE OF THE HUMAN PATELLA

In Speed's "Collection of Fractures at the Cook County Hospital, Chicago," fractures of the patella equal 1.67 per cent of the total number. Very few are open fractures and they occur primarily in the fourth decade of life and are found more than twice as frequently in men as in women.

The causes are of two kinds—direct violence, as in a blow or fall on the patella, or indirect violence, from an unexpected, forcible contraction of the quadriceps muscle, or sudden flexing of the leg with this muscle in strong contraction, illustrated by Speed as in the case of a foot caught between immovable objects and a sudden pushing over of the body into a sitting posture, while effort is being made to stand erect. Falls or direct violence also account for the incomplete fractures or the complete type without separation.

The greater percentage of all breaks, with the customary transverse line of fracture in the lower portion, are due to indirect violence (Speed, 1916; Page and Bristow, 1923). The transverse or oblique fractures are most frequently situated in the lower third, not only due to the fact that the triangular shaped patella is the most commonly found, but because the traction trabeculæ form thinner laminæ of bone in this location and those that are present are frayed out. This forms a weakened zone or vulnerable structure in the lower one-third of the patella as resistance against sudden strains due to tension.

According to Speed, with the leg semi-flexed the patella lies at the highest point at the condyle of the femur in a position of weakness and non-support on the intercondyloid fossa, as shown in Figure 1, Plate VIII. Sudden strain from flexion of the leg or contraction of the quadriceps will thus tend to snap the patella and tear the ligaments. While the lower fragment is held securely by the patellar tendon, the upper fragment tends to retract farther through the contraction of the quadriceps muscle, which has lost its anchorage to the tibia. The lower fragment is rotated a little, so that its broken surface tilts forward, while the upper fragment usually takes the opposite displacement, its broken surface tending to turn toward the joint cavity or to be rotated posterior (Fig. 1, Plate VIII). Another explanation for this type of displacement of transverse fractures in the patella is due to the arrangement in an oblique direction of the pressure pillars in the lower one-third of the patella. These pressure pillars are directed from the ventral surface of the patella dorsocephalad (Fig. 1, Plate VIII). In cases of indirect violence the cleavage plane of the fracture would like-

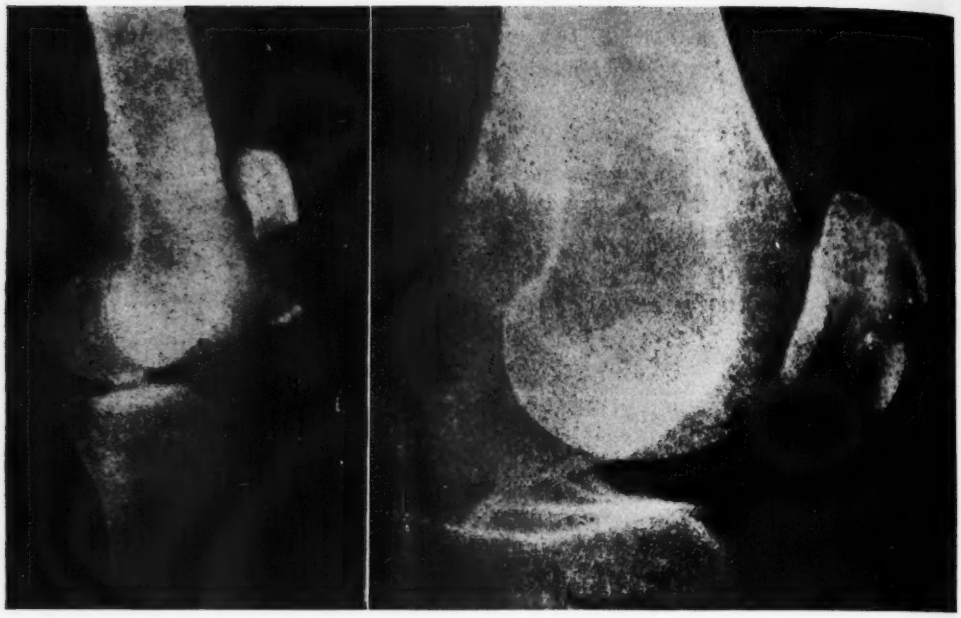

Plate VIII. Fig. 1. Transverse fracture of the patella with separation. (After Page and Bristow.)
Fig. 2. Stellate fracture of the patella. (After Page and Bristow.)

wise tend to be directed obliquely, corresponding to the intervals between the obliquely directed pressure pillars.

The attenuation and vulnerability of the traction trabeculæ in the lower one-third of the patella on its ventral aspect would explain the cause of the greater frequency of transverse fractures due to indirect violence in the lower one-third of the patella, together with the fulcrum action of the articular surface of the femur (Fig. 1, Plate VIII). The type of displacement, furthermore, is explicable by the oblique direction of the pressure pillars in the lower one-third of the patella. Due to the attachment of the patellar tendon in relationship to the lower one-third, the lower fragment will be slightly rotated.

The stellate type of fracture is due to direct violence (Fig. 2, Plate VIII). The superimposed plates of traction trabeculæ will tend to be cracked like a plate of glass in a stellate manner, depending upon the nature of the direct force. The traction trabeculæ are not built to withstand forces directed at right-angles to the long axis of the laminæ of the bone. They are built to withstand tension, consequently stellate fractures are frequently incomplete because, once the force has caused a rent in the traction trabeculæ, a more resistant group of pressure pillars tend to counteract the influence of the direct force of pressure. The long axes of the pressure pillars are directed, like the spokes of a wheel, from the ventral convex circumference of the patella toward the articular surface, converging as the hub. The pressure pillars are not built to withstand tension or sudden pull at right-angles to their long axes. This arrangement of the pressure pillars explains the frequency of complete transverse fractures in the lower one-third of the patella, because the greater amount of bone, not only here but throughout the patella, is built to withstand pressure ventrodorsad rather than traction cephalo-

caudad, in the ratio of approximately four to one (Plates I, II, and III).

CONCLUSIONS

1. The embryologic study and experiments on the genesis and regeneration of the patella emphasize the known clinical principles of early massage and mobility (passive and active), applied in the treatment of fractures, first introduced by Lucas-Championniere and advocated by Robert Jones, Lovett, Hey Groves and many other clinicians.

2. The general practitioner must know the functional anatomy of bones, muscles, joints, and related nerves and vessels of a limb, if he attempts to restore function in a limb after a bone is broken. The problem is not purely the bone, but one of interaction of bones, muscles, and joints. If chance be not relied on, then a keener insight into the interactivity of living parts is imperative. Those who attempt to treat cases of fracture without this knowledge do so in the dark and their results are a product of chance.

3. Under adequate mechanical conditions produced by an intact, normally mobile knee joint and its related soft parts, patellar cartilage and bone regenerate from young connective tissue cells which have not been destined as specific forms of bone.

4. When adequate mechanical conditions are altered by means of immobilizing the knee joint (arthrodesis), with the patella left intact, patellar cartilage and bone atrophy.

5. When the patella is excised *in toto* and adequate mechanical conditions are altered by means of knee joint fixation, patellar cartilage and bone do not regenerate, even if the tendon of the quadriceps extensor femoris muscle be united by suture with the patellar ligament.

6. The "adequate mechanical conditions" are a normally mobile, exercising articulation, with the soft parts replaced, a condition met in the case of a knee joint where the patella is excised and the tendon of the quadriceps extensor femoris muscle sutured to the patellar ligament with quickly absorbable material.

7. There was a dynamic interaction (mobilization) of the parts forming the limb, displayed in intra-uterine life, transforming bone, muscle, and joints from the potential to the actual state. The functional interactivity, which replaces differential growth in the adult, is one of the sustaining influences maintaining the normal external form and internal structure of bones, muscles, and joints in the adult. No integer of this triumvirate may be displaced or fixed without affecting the other two.

8. *Differential growth and resistance.*—The stresses elicited which cause the origin of bone from the subperiosteal mesenchyme are the result of differential growth and resistances to growth. The accelerated growing blastemochondrogenous skeleton meets the following resistances: (1) Opposed growth of contiguous skeletal segments; (2) weight of related soft parts; (3) reactive elasticity of traction of the soft parts retarded in growth; (4) active muscular pull. It is imperative, therefore, that (1) growth and (2) resistances to growth be understood by the embryologist and clinician, before he can appreciate the importance of each factor. Both are active and formative during development and repair; both are absolutely necessary to the realization of form, and neither process can be looked upon as more important in development than the other.

9. The origin of intratendinous zones of ossification, such as the patella, and known as the sesamoid bones, is due to an adequate degree of intermittent or remittent traction and pressure, induced as stresses, in a tendon where it repeatedly bends over a bony surface of a movable joint, like the rope of

a pulley. Tension is produced by the pull on the tendon by the muscle and pressure by the compression of the tendon where it bends over a bony surface of a movable joint. Pure tension, unrelated to pressure, is not an adequate stimulus to originate bone. The action of tension related to pressure arranges the bone generated by pressure along lines of adequate traction.

10. Therefore, the patellar bone is dependent in origin and structure, being neither self-made nor self-supporting. Its existence is contingent on the integrity of the limb as a whole; on the mobility of the knee joint and the pressure, tension, and friction induced by the normal functional activity of the quadriceps extensor femoris muscle on its tendon that passes over the ventral aspect of the lower end of the femur. Adequate optimum intermittent pressure is an efficient stimulus to originate patellar bone. The arrangement of the bone is dependent upon tension as well as on pressure.

11. The arrangement in the patella of the traction trabeculæ and pressure pillars induced by muscular and knee joint mobilization during development and adult maintenance, explains the frequency and location of certain types of fractures and their displacements in clinical practice.

LITERATURE CITED

BARD, L.: Manual d'anatomie, 1891.

BARDEEN, C. R.: Johns Hopkins Rep., 1900, VIII, 231.

BARDEEN, C. R., and LEWIS, W. H.: Development of the Limbs, Body Wall, and Back in Man. Am. Jour. Anat., 1901, I.

BERNDT, F.: Zur Frage der Betheiligung des Periostes bei der Muskelverknöcherung nach einmaligem Trauma. Arch. f. klin. Chir., 1901, Bd. 65, S. 235.

BERTHIER, A.: Etüde histologique et experimentale des osteomes muscularis. Arch. de med. exper. et d'anat. path., 1894, T. 6, p. 601.

CAREY, EBEN J.: Preliminary Report on the Normal Unequal Growth and Degeneration in the Early Ossification Centers in the Diaphysis of Femora of the Pig. Anat. Rec., 1917, II, No. 6.

Idem: Early Stages in the Development of the Pig, with Reference to the Influence of Muscular Activity upon Its Ossification. Anat. Rec., 1918, XIV, No. 1.

Idem: On the Interaction of the Primary Femoral Ossification, Thigh Muscular Differentiation, Knee- and Hip-joint Formation, during the Period of Rotation of the Hind Limb of the Pig. Anat. Rec., 1919, XVI, No. 3.

Idem: Teratological Studies. Anat. Rec., 1919, XVI, No. 2.

Idem: Studies in the Dynamics of Histogenesis. I.—Tension of Differential Growth as a Stimulus to Myogenesis. Jour. Gen. Physiol., 1919, II, No. 4.

Idem: II.—Tension of Differential Growth as a Stimulus to Myogenesis in the Esophagus. Jour. Gen. Physiol., 1920, III, No. 1.

Idem: III.—Growth Motive Force as a Dynamic Stimulus to the Genesis of Muscular and Skeletal Tissues. Anat. Rec., 1920, XIX, 199.

Idem: IV.—Tension of Differential Growth as a Stimulus to Myogenesis in the Limb. V.—Compression between the Accelerated Growth Centers of the Segmental Skeleton as a Stimulus to Joint Formation. VI.—Resistances to Skeletal Growth as Stimuli to Chondrogenesis and Osteogenesis. Am. Jour. Anat., 1921, XXIX, No. 1.

Idem: Direct Observations on the Transformation of the Mesenchyme in the Thigh of the Pig Embryo (Sus Scrofa), etc. Jour. Morph., 1922, XXXVII, No. 1, pp. 1 and 6.

Idem: XII.—The Regeneration of the Patellæ of Dogs. Am. Jour. Anat., Sept. 15, 1927, XL, No. 1, p. 127.

LUCAS-CHAMPIONNIERE, JUST: The Treatment of Fractures by Mobilization and Massage. Brit. Med. Jour., Oct. 3, 1908, II, No. 54,898.

EWALD, P.: Zentralbl. f. Chir., 1911, Bd. 37, S. 771.

FRANGENHEIM, P.: Arch. f. klin. Chir., 1905, Bd. 80, S. 445-450.

GILLETTE, P.: Des os sesamoides chez l'homme. Jour. de l'anatomie et de la physiologie, 1872, p. 506.

GRAF, E.: Die konigliche Reserve Lazarethe zu Düsseldorf wahrend des Krieges, Elberfeld, 1872.

GROVES, E. W. HEY: The Treatment of Fractures. William Wood & Co., 1922, p. 194.

HILTON, JOHN: Rest and Pain. William Wood & Co., 1879.

JANSEN, MURK: On Bone Formation. Manchester, 1922.

JOHNSTON, O.: Epilunar and Hypolunar Ossicles. Jour. Anat. and Phys., 1906, p. 59.

JONES, SIR ROBERT, and LOVETT, ROBERT W.: Orthopedic Surgery. William Wood & Co., 1923.

KÖNIG, F.: Über traumatische Osteome, fracturlose Callugeschwülste. Arch. f. klin. Chir., 1906, Bd. 80, S. 64.

LUNGHETTI, A.: Contributo allo studie della morfologia e dello sviluppo dei sesamoidi intratendinei. Internat. Monatschr. f. Anat. u. Phys., 1905, Bd. XVI, p. 47.

MACEWEN, SIR WILLIAM: The Growth of Bone. Glasgow, 1912.

MARSHALL, H. W.: A Case of Myositis Ossificans Traumatica Developing from Torn Coracoclavicular Ligament without Other Bony Fracture. Boston Med. and Surg. Jour., April 14, 1921, CLXXXIV, 380.

MEYER, H.: Die Architectur der Spongiosa. Reichert u. Dubois, Reymond's Archiv. f. Anat., 1867, S. 23.

ORTH, J.: Zur Kenntnis des Knochenkallus. Berl. klin. Wchnschr., 1906, Bd. 43, No. 14, S. 430.
PAGE, C. MAX, and BRISTOW, W. ROWLEY: The Treatment of Fractures in General Practice, 1923.
PAINTER, C. F.: A Consideration of the Etiologic Factors in Myositis Ossificans Traumatica. Boston Med. and Surg. Jour., July 14, 1921, CLXXXV, 45.
PARSONS, F. G.: The Epiphyses of Bones. Jour. Anat. and Phys., 1905, p. 402-12.
PIRES DE LIMA, J. A.: On a Bone Found in the Vastus Externus of the Thigh. Jour. Anat. and Phys., 1913, XXXVII, n. s. XXVII.
ROUX, W.: Beiträge zur Morpholigie der Functionallen Anpassung, Beschreibung und Erläuterung einer knöchernen Kniegelenkankylose. Archiv. f. Anatomie u. Entwickelungsgeschichte, 1885, S. 120.
SEYDELER, R.: Deutsch. mil. Ztschr., 1879, Bd. 8, S. 33-48.
SPEED, KELLOGG: Fractures and Dislocations. Lea & Febiger, 1916.
THOMA, R.: Ein Beitrag zur Histomechanik des Skelettes u. zur. Lehre von dem interstitiellen Knochenwachstum. Virchow's Archiv., 1907, Bd. 188, S. 303.
ZSCHOKKE, E.: Weitere Untersuchung über das Verhaltniss der Knochenbildung zur Statik und Mechanik des vertebraten-skelettes. Zurich, 1892.

Fluctuation of the Albumin Content of the Serum: Its Importance and Change Following Light Exposure, with Particular Consideration of Tuberculosis. Erich Schneider. Strahlentherapie, 1927, XXVI, 586.

In normal persons the ratio of albumin to globulin in serum is two and a half to one. An increase in the globulin, particularly in tuberculous patients, as observed by the author, points to a progressing disease. The change of this quotient, fluctuation of the acid base equilibrium and the blood sugar, was examined following sun, ultra-violet (quartz mercury vapor lamp), and roentgen-ray exposure. It appeared that after exposure to any of the three types of irradiation the hydrogen ion concentration in the urine was increased. This points to a diminished alkali reserve of the organism. The viscosity of the serum was also changed. Patients having a high globulin content in the serum should be irradiated with great caution. No law for the blood sugar fluctuations following the light exposure could be deduced.

E. A. POHLE, M.D.

Investigations Regarding the Artificially Increased Permeability of the Skin for the Short Wave Length Range of the Spectrum and Regarding the Fluorescent Radiation of the Skin Irradiated with Ultra-violet Light. W. E. Pauli. Strahlentherapie, 1927, XXVI, 577.

In a recent paper the author reported that it is possible to increase the permeability of animal and human skin for rays above 4,000 Ångstroms (see this Journal, January, 1928, X, 84). This article relates the same experiments, dealing with short waves, from 4,000 Ångstroms to 2,000 Ångstroms. A solution of alcohol glycerin increases the permeability of the skin considerably. The fluorescence of normal skin was also studied. In accordance with Stokes' law, a primary radiation of 3,000 Ångstroms caused the emission of fluorescent rays of 4,600 Ångstroms: both figures represent the maxima. Very interesting is the close agreement of the skin erythema line at 2,970 Ångstroms with the wave length causing the maximum amount of fluorescence.

E. A. POHLE, M.D.

THE ADVANTAGE OF COMBINING METHODS OF TREATMENT IN PHYSICAL THERAPY[1]

By FRANK B. GRANGER, M.D., Boston

THE World War hastened the more general recognition of the value and the place of physical therapy in therapeusis. It also proved that not only were its various subdivisions interdependent but also that the same relationship existed between it and the other branches of medicine and surgery, including the laboratory.

Just as, during the War, standardization of X-ray apparatus was started, so, since the War, a similar standardization of the apparatus and methods of physical therapeutics is under way. For this purpose the American Medical Association has created a Council on Physical Therapy. This Council, in the main composed of eminent scientists, is making an intensive study of the manifold ramifications of physical therapeutics. To facilitate this purpose, certain problems have been assigned to the laboratories of the great universities, of commercial organizations, of private individuals, of certain scientific societies, and to some of those maintained by the United States Government. Similarly, from a clinical standpoint, use is being made not only of private, civil, military, and naval hospitals, but also of those connected with the medical schools. Hearty co-operation is also being given by the manufacturers, particularly those engaged in the production of electrotherapeutical apparatus. The War not only emphasized the fact that physical therapy should be used only as a part of the triad of medicine, surgery, and physical therapy, and only in conjunction with at least one of its sister members, but also that the subdivisions of physical therapy (*i.e.*, massage, electrotherapy, hydrotherapy, muscle-training, mechanotherapy, and physical exercise) should ordinarily be prescribed in combinations of two or more. An adherent scar is an example of this. Here, the most successful treatment consists of heat (generally that of hydrotherapy in the form of the whirlpool bath), electrotherapy, employing the chlorine ionic properties of galvanism, and massage.

In the merging of all these factors lies the future strength of medicine and its answer to the challenge of the cults.

Such laboratory and clinical studies will eventually place physical measures of treatment on a sound and scientific basis. When this is consummated, the time of disability will be shortened, greater success in functional restoration will be insured, many otherwise hopeless cripples will be restored to gainful occupations, and the economic tax, due to industrial accidents and occupational diseases, which is borne by the community at large, will be materially lessened.

The following are examples of the interdependence of treatment.

Anterior Poliomyelitis.—Here, the physician, the orthopedist, and the physiotherapist are concerned. In addition to proper orthopedic principles and apparatus, physiotherapy should also be employed. The latter should consist of electrotherapy, massage, and muscle-training. In order not to overtire the musculature, these treatments must be most carefully given. While the nerve impulses are blocked such electrotherapeutic measures should be selected as will tend to minimize the muscular atrophy, with its consequent histological changes, which would otherwise surely ensue, so that if

[1] Presented before the Radiological Society of North America, at the Thirteenth Annual Meeting, at New Orleans, Nov. 29, 1927.

and when the nerve tracts are free they can activate responsive muscular tissue. Ordinarily diathermy (internal baking) will, by causing an active hyperemia, flush the musculature and lessen the fibrillary contractions. Sinusoidal stimulation will give local muscle exercise, and massage will do its share in promoting the lymphatic circulation and maintaining the muscle tone. When the first flicker of voluntary motion is seen then careful muscle-training or re-education should be instituted as the best means of securing functional restoration. At the onset of the attack, radiant heat and diathermy frequently relieve the pain and tenderness so that the ofttimes prolonged period of waiting for the acute symptoms to subside will be greatly shortened, thus making possible the early use of more active measures of treatment.

Subdeltoid Bursitis.—Teamwork by the orthopedist or surgeon, the roentgenologist, and physiotherapist is essential. Few of these cases need operation. A radiograph is indicated to determine if calcification is present, and, if so, its extent. Later, serial examinations give a graphic description of its subsidence. Diathermy, followed by galvanism, massage, and gentle manipulation, suffices in the majority of cases. Some require an operation; others, the forcible breaking of adhesions under gas oxygen, over-correction in plaster for a short time, followed by radiant heat, massage, and active exercise to relieve pain and prevent the re-formation of adhesions.

Fractures.—The same team as in subdeltoid bursitis is necessary. In many cases only radiant heat, massage, and active assistive motion are necessary. Care, however, should be taken that such procedures do not degenerate into a bake-and-rub proposition. If there is delayed union or non-union, properly applied diathermy, at times supplemented by general ultra-violet irradiation, will frequently stimulate callous formation. Here again, serial radiographs will show the progress of the union.

Adenitis.—Adenitis, especially cervical, demands the attention of the physician or surgeon, the radiologist, and the physiotherapist. The treatment depends on the pathology. A soft fluctuant gland should be treated surgically, followed by such physical therapeutic measures as a general body irradiation by ultra-violet, in order to restore tone, or, if it is tuberculous in character, for the specific action of ultra-violet in such conditions. If a discharging sinus ensues, the local application of the water-cooled ultra-violet with a quartz sinus applicator, or local irradiation with the air-cooled ultra-violet, after the instillation into the sinus of a 2 per cent solution of mercurochrome will ordinarily cause prompt healing. The hard glandular type generally yields to X-ray treatment, followed by general ultra-violet irradiation.

Arthritis.—This will be so thoroughly discussed by Dr. Ralph Pemberton that only mention will be made of the value of diathermy in properly selected cases in securing symptomatic cures, which are frequently many months in duration.

Spinal Scleroses.—The neurologist and the physiotherapist can frequently work seeming miracles in some of these cases. Here again it must be remembered that remissions do take place, and that nerve substance which has been destroyed can not be regenerated. However, in the earlier stages the result may be otherwise. Diathermatizing the spine, with the production of an active hyperemia, apparently may cause nerve regeneration. If careful massage and muscle-training are added to this, the results may be still more brilliant.

Flat Foot.—This is essentially the province of the orthopedist and the physiotherapist. Treatment depends on the type, the majority of cases being, according to Cotton, of the "habitual" (reducible) type.

The treatment may be subdivided as follows:

1. *Mechanical* for temporary relief: Under this is included strapping to correct undue pronation, possibly shoes with Thomas heels and soles, and, at times, an inner sole with a felt pocket as a pad.

2. For relief of pain in the acute stage: Use *some form of heat,* such as hot soaks, whirlpool bath, or diathermy, followed by massage or vibration.

3. *For restoration of muscle tone:* This treatment should consist of exercises, and, if such exercises are persisted in by the individual, no other treatment ordinarily is necessary. However, very few patients will carry out the proper exercise twice a day, and therefore it generally is necessary to add to the voluntary muscle exercise some electrical aids, such as the slow sinusoidal, which may be preceded by diathermy.

Hemiplegia.—The internist or the neurologist and the physiotherapist should cooperate in the treatment of this condition. In its early stage, if due to brain hemorrhage, apparently absorption of the clot may be hastened by the use of cerebral galvanization. The sinusoidal hand-and-foot water bath is supposed to supply physiological cell stimuli which will minimize the changes in the musculature due to disuse. Massage and re-educational exercises will, in later stages, increase co-ordination to a marked degree. Complications, such as constipation, frequently yield to abdominal sinusoidalization. At times the blood pressure will be lowered by auto-condensation. These cases have been neglected in the past. Dr. Shepherd I. Franz has shown what competitive exercise will do for selected cases.

Low Back Strain.—This condition, especially if it is industrial compensatory in character, will tax the ingenuity of the orthopedist and the physiotherapist. All such cases should be radiographed in order to determine whether or not an arthritis coexists or if there be some congenital or anatomical abnormality. As muscle spasm is a predominant factor, for treatment use diathermy, which may relieve the spasm; follow this by adequate fixation, and as soon as possible add voluntary muscle exercise. This will in a short time in a fair parcentage of cases restore the individual to his daily occupation. If the disability is prolonged, a marked mental inhibition to work or exercise sets in, which may baffle all therapeutic measures.

Malignancies.—The physician, the surgeon, the roentgenologist, and the physiotherapist all are necessary. If the case is suitable for electrosurgery, an operator well skilled in these measures should determine what type of current should be employed and see that the proper technic is carried out. For post-operative treatment the use of X-ray or radium, or both, depends entirely on the judgment of the roentgenologist.

In a similar manner the whole gamut of diseases amenable to physical measures of treatment could be discussed, but this would result only in redundancy. In a paper of this sort only generalities are in order, and hence no attempt has been made to go into details of diagnosis, pathology, or technic.

It is, of course, assumed that careful teamwork has thoroughly established the diagnosis, that the pathology has been carefully worked out, and that where focal infection may be a cause, such has been sought for, and, if found, eliminated. In short, I have attempted to stress only the following:

1. That physical therapy is being placed on a rational and scientific basis.

2. That it should be used only as an adjunct to standard medical and surgical procedures.

3. That ordinarily a physical therapeutic prescription should include two or more of its subdivisions.

4. That in many surgical conditions functional restoration is dependent on physical therapy.

5. That in many pathological conditions the addition of physical measures of treatment secures results which either could not be attained without it, or which, if attained, would require much longer periods of time.

6. That teamwork with the other branches of medicine is essential.

Regarding Systemic Effects of Roentgen Rays. O. David. Strahlentherapie, 1927. XXVI, 419.

Exposure of any part of the body reduces the glucose content of the blood in normal persons as well as in cases of hyperglycemia. A change of the sympathetic tonus is probably responsible for this effect. The X-ray sickness may be explained on the same basis. Injections of strontium bromid lead to results as predicted by this hypothesis. Much valuable information regarding the action of roentgen rays is to be gained by studying their effect on the autonomic nerve system.

E. A. POHLE, M.D.

Regarding Changes of the Functional Stage of the Blood Vessels Following Roentgen Irradiation. Fourth Communication: Investigations on the Human Skin. N. W. Lazarew and A. Lazarewa. Strahlentherapie, 1927, XXVI, 347.

In this fourth paper of a series, the authors relate the results of their investigations dealing with skin capillary changes in the field of a roentgen erythema. The flexor side of the forearm of fourteen normal adults (8 males, 6 females) was exposed, seven to 50 per cent, three to 80 per cent, four to 90 per cent S.U.D. (60 K.V., 3 ma., 1.0 Al., 23 cm. F.S.D.; E.D. = 10 minutes). Observations were taken ranging from several minutes to one year after the exposure. Besides the capillary microscopy, functional tests by injecting adrenalin, caffein, morphin, a combination of adrenalin and caffein, and Ringer's solution or by applying tincture of iodin, permitted deductions as to the dilatation, contraction, the lymph reaction, and resorption. The response of the capillaries to heat and cold was also examined. It appears that the erythema occurs in cycles (Miescher) and the macroscopic and microscopic reactions run parallel (Pohle). During the first hour after irradiation a spastic period is usually seen, followed by dilatation and increased permeability. The whole phenomenon is nothing but an inflammatory process, as any other erythema, for instance, the light erythema.

E. A. POHLE, M.D.

CASE REPORTS AND NEW DEVICES

A CASE OF CHRONIC APPENDICITIS AND CALCIFIED FIBROID UTERUS

By ROBERT A. ARENS, M.D., and ARTHUR R. BLOOM, M.D.,

Roentgenologist and Assistant Roentgenologist, Respectively, Michael Reese Hospital, CHICAGO

Mrs. C. S., aged 67, a patient of Dr. Solomon Strouse, was referred to us for roentgen study. Although the patient had been in poor health for many years, her latest illness came on about six months prior to her entrance into the hospital. She complained of a griping pain in the epigastrium, coming on one to two hours after eating, often radiating to her right shoulder and back and usually followed by severe abdominal cramps, which at times would awaken her at night. This pain was of such severity that often a narcotic was required. Spirits of ammonia in milk and hot application to the abdomen often relieved the pain when not too severe.

The patient frequently vomited after an attack, thereby usually relieving the distress. The vomitus was bile-stained. Belching was also common, and she felt better after it. She also complained of weakness, which had become marked of late, and believed that she had lost some weight.

The past and family histories were irrelevant. Menopause came at the age of forty-five. For twenty-three years she had noted the presence of an abdominal mass. There was no abnormal vaginal bleeding.

Physical examination showed a fairly well nourished woman who was not acutely ill. The temperature was 97.6° F., pulse 76, and respiration 18. There were a few tender cervical glands on the left side. A systolic murmur was heard over the pul-

Fig. 1. Colon at 24 hours, showing barium-filled appendix in relation to fibroid uterus.

Fig. 2. Opaque enema, showing ileocecal incompetency and barium-filled ileum surrounding the fibroid uterus.

monic area. There was tenderness of the abdomen midway between the xiphoid process and the umbilicus. The edge of the liver was just palpable, and smooth. A large hard tumor mass was felt through the abdominal wall, extending from the pelvis to within 3 cm. of the umbilicus. It was tender on deep pressure.

Laboratory Findings.—Examinations of stool and stomach contents were negative. The urine was acid, with a specific gravity of 1.036, contained a trace of albumin, and microscopically showed a few white cells and an occasional red cell. The blood examination revealed 5,400,000 red corpuscles and 9,600 white cells, with 61 per cent neutrophils, 31 per cent small lymphocytes, and 8 per cent large lymphocytes. The hemoglobin was 75 per cent.

On fluoroscopic examination a hypertonic stomach was found, the greater curvature extending to the crest line. There were no defects and it was freely mobile. Motility was five hours. The duodenal cap filled out perfectly and likewise was freely mobile. There was moderate tenderness in the gall-bladder region. At 24 hours the barium was distributed throughout the colon. The appendix was long and tender and adherent to a tumor mass in the lower abdomen, which cast a dense shadow. At 48 hours the cecum was empty, but the appendix was still filled as at 24 hours and was tender.

The colon filled out completely after an opaque enema, and showed no defect other than a tubulization of the descending branch. The ileocecal valve was incompetent, and, as the ileum filled, the tumor mass was surrounded and outlined by the opaque medium. The films confirmed the fluoroscopic examination and revealed a normal stomach, duodenum, and colon. Primary gall-bladder film showed a gall-bladder shadow. A tumor mass of the size, shape, and density of a large fetal head but presenting the characteristic appearance of a calcified fibroid was revealed, rising out of the pelvis. A roentgen diagnosis of chronic appendicitis, calcified fibroid uterus, and pathological gall bladder was made. The patient refused an operation.

In our experience calcified fibroid uteri are not common, having been seen only about three or four times in the last five years. In combination with an adherent, chronically inflamed appendix, the case is of more than passing interest.

A SIMPLE METHOD FOR THE DETERMINATION OF THE ELECTROSTATIC CAPACITY OF ELECTROSCOPE

By ROBERT B. TAFT, M.D., B.S.,
Riverside Infirmary, CHARLESTON, S. C.

The determination of the electrostatic capacity of the electroscope-iontoquantimeter by either the potential-drop or radio frequency method requires special apparatus and is, at best, an extremely delicate procedure.

The following simple method necessitates no apparatus not found in any roentgen department or roentgenologist's office, and seems to give very uniform results. Assuming that one has a standard condenser checked by the Bureau of Standards or other authoritative source, we proceed as follows:

Place a small amount of radium element on or near the ionization chamber, screening it properly with lead from the rest of the system. Time the fall of the leaf over any convenient part of the scale. Then connect the standard condenser in parallel with the system (that is, connect one side of the standard to the post supporting the leaf and ground the other side), and again time the fall over the same scale. Of course, if there is an error caused by leak it must be cor-

rected for in the usual manner. As the time of the fall is directly proportional to the capacity under similar conditions, we derive this proportion—

$$\frac{C}{C+S} = \frac{T}{I}$$

Where C = Capacity of system.
S = Capacity of standard.
T = Number of seconds of fall without standard.
I = Number of seconds of fall with standard.

When simplified, this gives

$$C = \frac{ST}{I-T}$$

The author realizes full well that most roentgenotherapists prefer the standardization of instruments by biological means, but those who, for their own interest, do wish to determine the electrostatic unit by calculation of the electrical and mechanical factors will find this a simplified method of making one of the steps.

AMERICAN ASSOCIATION OF RADIOLOGICAL TECHNICIANS

The Program Committee of the American Association of Radiological Technicians desire to thank all members who have signified their intention of appearing on this year's program, which will be held in Chicago the week of April 23. Although the program is nearing completion there is yet opportunity for several more contributions to be added. Please notify the Program Committee at once, if you have any material to present. All communications should be sent to H. A. Tuttle, Chairman, 221 La Salle Building, Minneapolis, Minn.

EDITORIAL

CHRONIC DUODENAL STASIS

In chronic duodenal stasis there is an abnormal retention of duodenal contents in the second and third portions, usually associated with one or more associated signs such as "writhing," antiperistalsis, and dilatation. This should not be confused with duodenal obstruction resulting from direct encroachment on the lumen of the viscus by malignancy either intrinsic or extrinsic, benign stricture, impaction by gallstones, etc.

The causes attributed to chronic duodenal stasis by various authors are legion. Kinking of the duodenum, especially at the duodeno-jejunal junction, is given as one of the most common causes. Abnormal bands and adhesions may be present. Pressure of the root of the mesentery is given as a frequent etiological factor. Ptosis of various abdominal organs, including the stomach, duodenum, and cecum, is also frequently associated with this condition. In a recent article Bloom and Arens state that chronic duodenal stasis due to the above causes is, in their experience, rare. They state that duodenal stasis is not a clinical entity but a radiologic sign seen in various conditions such as cholecystitis, cholecystolithiasis, and duodenal ulcer.

It will be seen from the above that the diagnosis of chronic duodenal stasis is a physiological problem capable of producing wide variations of opinion, and in which, perforce, the element of personal equation frequently will be reflected in the diagnosis. This is shown by the diverse opinions expressed in the literature regarding the causes of the stasis and the meaning of the resulting roentgenological signs.

The symptoms and signs vary according to the portion of the duodenum involved and are very frequently not diagnostic and often not very suggestive. We are, then, faced by the fact that the roentgen ray is the instrument *par excellence* for determining the presence of this condition, its location, its severity, and possible cause. It, therefore, behooves us as roentgenologists carefully to study this condition and formulate, if possible, definite diagnostic criteria.

The one important sign is stasis, as the name indicates. One must be careful, however, that this is pathological stasis and not an unusual filling of the duodenum due to a very rapid emptying of the stomach, or a temporary stasis due to some mechanical factor, such as position of the patient during examination. In true duodenal stasis there is in the majority of cases an accompanying dilatation, the extent depending on the severity of the obstruction and the length of time it has existed. This, of course, attains its greatest prominence in those cases of organic obstruction. Antiperistalsis is the sign which requires careful observation and study to evaluate its significance. Several authors state that this is seen very frequently in otherwise normal cases, and we have recently observed it in about 75 per cent of a small series of routine gastro-intestinal cases where it was carefully

searched for in the various positions, and by using manipulation. In those cases of chronic stasis the antiperistalsis is usually of a powerful type, forcing the entire column of barium back into the cap, and in long-standing cases, where the pyloric sphincter is relaxed, even into the stomach.

It would seem that in a true case of chronic duodenal stasis these signs should be observed on repeated examinations and with the patient in various positions.

Recently a very valuable symposium on this subject has been published in RADIOLOGY, July, 1927, IX, No. 1. The subject has been considered from all angles, including a review of the normal physiology of the duodenum. A careful study of these articles cannot help but be beneficial to every roentgenologist.

HOWARD P. DOUB, M.D.

THE CANADIAN RADIOLOGICAL SOCIETY

At the last annual meeting held in conjunction with the Canadian Medical Association the Canadian Radiological Society decided to merge its existence as a special society in the Canadian Medical Association. Henceforth it will function as a section of the general organization.

In this way the Radiological Section will make its contribution to the program of the general Society, and thus greatly facilitate the extension of X-ray propaganda among the general profession. At the same time it will retain its capacity to function in a corporate way in dealing with the problems that confront the radiologists of Canada.

PHOTOGRAPHING THE SPEED OF THE HUMAN BLOOD-STREAM

By the use of a device which records the presence of a ray given off by radio-active material, the motion of the human blood-stream is being measured and analyzed by Dr. Herman Blumgart at the Thorndike Memorial Hospital in Boston, Mass. This device, known as the Geiger Electric Counter, is so sensitive that it will detect the presence of emanations so weak that chemical analysis cannot bring them to light.

Radio-active preparations are injected in small quantities into the blood-stream of the patient, and with the Geiger apparatus are detected as they reach different parts of the circulatory system. A strip of motion picture film used in connection with a sensitive reflecting galvanometer, or a siphon recorder similar to those used in trans-Atlantic telegraphy, serves to make records of the active material as it passes the point at which the Geiger detector is held.

The original apparatus was devised by Hans Geiger, a German scientist, in 1906, for the purpose of making quantitative studies of the emanations of radium. Recently, Dr. C. W. Hewlett, of the General Electric Research Laboratories, improved the device, so that its indications are easily controlled and reliable.

The apparatus consists of a small brass chamber within which a very sharp platinum needle is held by an insulating collar. The chamber is closed at one end with a hard rubber plug and at the other by a thin aluminum plate, and a direct-current potential of 1,500 to 2,000 volts is maintained between the needle and the chamber wall. When a radio-active ray enters through the aluminum window, ionization of the enclosed air takes place, and in the intense electrostatic field at the point of the needle a current rush is set up that is many thousand times as large as that represented by the original ray. If some detecting device such as high impedance radio head 'phones, a string galvanometer, or a siphon recorder is connected in the high-potential circuit with the needle, the impulses set up by the ray can be read or recorded. By suitable amplification, the impulses can be built up

Portrait by Sid Whiting, St. Louis.

EDWIN C. ERNST, M.D.
President of the Radiological Society of North America.

to such an extent that relays may be operated, or a loud speaker made to register the sound.

The apparatus developed by Dr. Hewlett is contained in a box about three feet long and a foot square, and consists of a kenetron rectifier and filter equipment for supplying the high potential, and a special amplifying set. The Geiger chamber is portable, being encased in hard rubber and connected to the amplifier by a flexible cable. Chamber, cable, and apparatus box are all carefully shielded to protect them from stray electrostatic disturbances in the room.

As used by Dr. Blumgart, one or several chambers are placed on various parts of the patient's body, radio-active material is injected into the blood stream, and the time of arrival is recorded on the tape or film. Since the active rays will penetrate the body without difficulty, readings may be taken at any desired point without making an incision.

In addition to its medical uses, the improved apparatus is being employed in the study of radio-active materials used in vacuum tubes, and also for checking up various theories in physical chemistry which have so far eluded experimental investigation.

DR. E. M. E. SUNDELOF-ERICSSON

IN MEMORIAM

Dr. Ester M. E. Sundelof-Ericsson, formerly of Boston, recently died in New York after a short illness. She was a graduate of the Girls' Latin School, Boston, and was graduated from Tufts College Medical School with honors in June, 1916, receiving the degree of Doctor of Medicine. She was well known both in Boston and New York as an X-ray specialist.

While in Boston, before her marriage, she held positions of note at the Boston City Hospital (the only woman doctor ever admitted to its staff), the Lynn Hospital, the New England Hospital for Women and Children, was connected with the X-ray Laboratory of Boston, and with the Truesdale Hospital in Fall River. In 1918 she accompanied the Grenfell Expedition to Labrador, where she installed Dr. Grenfell's X-ray apparatus, and was actively engaged for several months with him in his work among the fisher folk.

Dr. Sundelof-Ericsson was a member of this Society, and many friends will learn with sadness of her early death.

AUGUSTUS ROBERT TAFT, M.D.: DECEASED

Dr. A. Robert Taft, who died September 20, 1927, of angina, aged 53, was known as a charming gentleman and an able leader and teacher among the members of the medical profession of South Carolina. He was a member of the Radiological Society of North America, the American Medical Association, the American Roentgen Ray Society, and the American Radium Society. He served during the World War.

CELLULOSE FILMS MAY REVOLUTIONIZE PHOTOGRAPHY

Cellulose, the principal constituent of wood fiber, may revolutionize photographic methods by its use in photographic films. A new process has just been developed by Philippe David, collaborator of A. Bertillon, famous criminologist, by means of which it takes the place of gelatin as a support for the sensitive silver salts.

In the ordinary photographic plate or film the base of glass or celluloid is coated with a layer of gelatin in which are suspended the silver bromide particles. The gelatin layer is rather delicate, and great care must be taken with the films or plates before they

are dry. Too much heat will melt the coating and spoil the picture.

With the new films gelatin and its disadvantages are eliminated. (As the cellulose does not dissolve even in boiling water, the developing chemicals may be used hot to speed up the process.) They may be developed in three to four minutes, fixed in two minutes, and washed in thirty seconds, instead of the fifteen to thirty minutes that the latter process now takes. Then they can be dried over a flame or in a hot oven in two or three minutes. The entire process, from the start of development to the dry negative ready for printing, is over in ten minutes at the most. This is a far shorter period than can be obtained at present.—*Science Service.*

THE 1927 NOBEL PRIZE AWARD IN PHYSICS

"Since the discovery of spectrum analysis no scientist could doubt that the problem of the atoms will be solved when we have learned to understand the language of their spectra."[1]

While investigating this "language" Dr. Arthur H. Compton discovered that under certain conditions an X-ray spectrum line had shifted from its expected position. For his recognition of the significance of this shift (the Compton effect), and the development of his quantum theory of X-ray scattering, and the researches supporting this theory, he was awarded the 1927 Nobel Prize in Physics. This prize, given for notable contributions to knowledge, has come to America three times: first, in 1907, to A. A. Michelson; second, in 1923, to R. A. Millikan, and third, in 1927, to A. H. Compton. All three at the times of the awards were professors of physics at the University of Chicago.

The Compton effect is a discovery of the greatest importance in our understanding of the nature of X-rays themselves and light in general. It is, that an X-ray of any given wave length becomes an X-ray of a longer wave length (a softer X-ray, *i.e.*, the X-ray has lost energy and momentum) when it strikes and glances from (is scattered from) an electron, the change in wave length increasing with the angle of scattering, being greatest for X-rays scattered straight back from the electron; and, further, that the scattering electron behaves as though it had been hit by a solid body. To quote Dr. Compton: "We find that the wave length of the scattered rays is what it should be (*i.e.*, longer) if a quantum of radiation bounced from an electron, just as one billiard ball bounces from another. Not only this, but we actually observe the recoiling billiard ball, or electron, from which the quantum has bounced, and we find that it moves just as it should if a quantum had bumped into it. The obvious conclusion would be that X-rays, and so also light, consist of discrete units, proceeding in definite directions. . . ."[2]

Physicists for years have considered the principles of the conservation of energy and momentum, and the spherical wave theory of radiation as being virtually statements of fact, but, "if this work [Dr. Compton's] on the scattering of X-rays and the accompanying recoil electrons is correct, we must therefore choose between the familiar hypothesis that electromagnetic radiation consists of spreading waves, on the one hand, and the principles of the conservation of energy and momentum on the other. We cannot retain both. . . . Unless the experiments . . . have been affected by improbably large experimental errors, I can see no escape from the conclusion that the fundamental assumptions on which the quantum theory of scattering is based are valid. To

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[1] Sommerfeld, A.: Preface to Atombau und Spektrallinien.

[2] Compton, A. H.: X-rays and Electrons, Chap. IX. D. Van Nostrand Co., New York.

be specific, (1) that the incident X-ray beam is divisible into discrete units possessing energy and momentum, and that these units, or quanta, may be scattered one at a time in definite directions by individual electrons, and (2) that when a quantum is scattered by an electron, energy and momentum are conserved in the process. How these conclusions are to be reconciled with the experiments which have led to the wave theory of radiation is another and a difficult question. The very considerable success of the wave theory as applied . . . to problems of the intensity of X-ray scattering gives confidence that such a reconciliation must be possible. . . . However, existing evidence demands that we adjust our ideas to include the existence of directed quanta of electromagnetic radiation."[2]

The work of Dr. Compton is not alone important in the field of physics. It should be of great value in the interpretation and understanding of the physiological action of X-rays in therapy.

"Who's Who in America" tells us that Dr. Compton was born in Wooster, Ohio, in 1892; received his Ph.D. from Princeton in 1916; married Betty Charity McCloskey of New Waterford, Ohio, in 1916; was instructor in physics at the University of Minnesota, 1916-17; research physicist for the Westinghouse Lamp Co., 1917-19; National Research Fellow in Physics at the Cavendish Laboratory, Cambridge, 1919-20; Professor of Physics and head of department at Washington University, 1920-23; Professor of Physics at the University of Chicago since 1923. This past year he has been a Guggenheim Foundation Fellow.

Though chiefly concerned with X-rays as they relate to physics, Dr. Compton has always shown a very sympathetic interest in the problems that confront the radiologist and physicist working in the field of X-ray therapy. Many of the members of the Radiological Society of North America will remember the paper he read to them at the Chicago meeting of 1924.

H. N. Beets, M.S.

NEW CANCER DIAGNOSIS METHOD PROMISES ADVANCE IN MEDICINE

The development of a method of diagnosis for certain kinds of human cancers, accomplished by Dr. George N. Papanicolaou, of Cornell Medical College, is an advance in the campaign that science is waging against this disease.

By a simple microscopic inspection of the fluids of a part of the body apart from the location of the malignant growths, Dr. Papanicolaou is able to detect the presence of the cancers. The appearance of the cells that have been injured in their fight against the abnormal growth is different from that of healthy normal cells.

Although the research is as yet in its early stages and the scientific details are not yet published, it is probable that the new diagnostic method will eventually be available for clinical use and that it will enable a physician to make the diagnosis of malignancy in its early stages when it can be best attacked and checked.

Cancer is caused by normal cells running wild and growing with a vigor that is otherwise shown only in the young, embryonic tissues. Such unruliness of mature cells attempting to create cancers is attacked by defenders of the body's health, the phagocytes and related cells, many of which are wounded in the combat and bear the marks of battle that Dr. Papanicolaou observes and uses as a diagnostic indication.

The cancers that Dr. Papanicolaou can detect by his new method are those of the female genital organs and the detecting cells occur in the genital tract. There is hope that the same method of diagnosis may be applied to other fluids of the body, thus easily lo-

cating malignant growths in other parts of the human machine.

The discovery was made as a by-product of fundamental work on the nature of sex in women. Following successful investigations of the sexual cycle of guinea pigs and other mammals, the same methods of research were applied to women in health and disease, with results that promise to confer real blessings upon the human race just as soon as they are developed and taboos are overcome to allow their application.—*Science Service.*

POST-GRADUATE STUDY IN VIENNA

The faculty of medicine of the Vienna University arranges courses of lectures in German every year, in order to enable doctors to continue and complete their studies, and to give them an opportunity of training in special branches.

The syllabus of these lectures is to be found in the official catalogue for the year 1927-28 (October 1, 1927–September 30, 1928), which can be obtained *free of charge* at the "Kursbureau" of the Vienna medical faculty, Wien VIII, Schlösselgasse 22.

The conditions for attending these lectures are also to be found in this catalogue. All further information is given free of charge, but applicants by letter are requested to enclose an international stamp-coupon for reply. Doctors are also given full information concerning board and lodging.

Four times a year—in February, June, September, and November—International Finishing Courses, lasting two weeks each, are being arranged, dealing with the progress in the different special branches.

The syllabus of these courses of lectures can be obtained from the Secretary, Dr. Kronfeld, Wien IX, Porzellangasse 22, and at the "Kursbureau" of the Vienna faculty of medicine, Wien VIII, Schlösselgasse 22.

Doctors wishing to attend the courses can apply to either of these offices.

ABSTRACTS OF CURRENT LITERATURE

Regarding the Radiation Therapy of Female Genital Tuberculosis. Erwin H. Zweifel. Strahlentherapie, 1927, XXVI, 564.

After a discussion of the literature and statistics regarding the subject, the author reports 24 cases of genital and peritoneal tuberculosis (diagnosis verified by biopsy) observed in the gynecological clinic in the University of Munich, from 1914 to 1924. Three cases of tuberculosis of the endometrium were treated by curettage and roentgen or radium application. All were cured after two, two and a half, and nine years. Of nine cases of tuberculosis of the adnexa, eight were operated on (exploratory laparotomy and drainage), followed by roentgen or radium treatment. Eight were improved or cured, one died from an unknown cause. Radiation of short wave length as used in deep therapy is recommended, 10 to 15 per cent E. D. effective in the diseased tissue. Other measures should always support the radiation therapy.

E. A. POHLE, M.D.

Ewing's Sarcoma: A Report of a Case. J. E. Pritchard. Can. Med. Assn. Jour., October, 1927, XVII, 1164.

A girl aged 16 was admitted into the Winnipeg General Hospital in July, 1926. Five months previously she had injured the right arm by falling upon it while skating. Following the injury there were periodic attacks of pain, with intervening intermissions. Five months after the accident pain became continuous. On the dorsum of the arm there was a definite hard swelling connected with the bone. The X-ray showed elevation of the periosteum. Following a diagnosis of osteomyelitis the tumor was incised and pus-like material evacuated.

A month later new bone formation showed on the X-ray film, and a diagnosis of sarcoma was made, after the study microscopically of a section taken for biopsy.

The tumor now rapidly increased. A few months later metastases began to appear, first in the iliac bone, and later in the spine, sternum, and skull.

Autopsy showed these metastases to be soft grayish tumors. Microscopically they were composed of irregular lobules, filled with sheets of small polyhedral cells with round nuclei, scanty cytoplasm, and no intercellular stroma. The entire picture—clinical, radiological, and pathological—is characteristic of Ewing's sarcoma.

L. J. CARTER, M.D.

Light Therapy of Roentgen and Radium Injuries of the Skin. Axel Reyn. Strahlentherapie, 1927, XXVI, 544.

Reyn advocates, in this paper, carbon arc therapy of X-ray and radium late reactions. A special apparatus permitting the cooling and compression of the exposed area is used. Of 21 cases, 4 left without finishing the treatment; of the 17 remaining patients, 13 were cured, 1 did not respond at all, and 3 are still under treatment. The author believes that the success is due to the stimulation of the capillaries to new growth, followed by the formation of connective tissue. This explains the very satisfactory scars which form after the treatment. Telangiectasis is sometimes improved by long-continued application of small doses.

E. A. POHLE, M.D.

An Early Case of Congenital Pyloric Stenosis. L. P. MacHaffie. Can. Med. Assn. Jour., August, 1927, XVII, 946.

The author presents a case report of this very rare condition—a complete occlusion of the pylorus in the newborn, due to stenosis.

Cyanosis, preceded by gagging, developed immediately after birth. On attempting to wash out the stomach the fluid was ejected, with gagging and cyanosis. Five per cent lactose solution was readily taken by the mouth, but was ejected in half an hour.

For diagnostic purposes, one ounce of barium mixture, given by gavage, revealed the stomach to be the size and shape of a lemon. The pyloric end had the appearance of a nipple, like the projection at the end of a lemon. No barium passed the pylorus. In a

few minutes the barium was ejected in a projectile fashion.

At operation, performed thirty-four hours after birth, the pylorus was found to be completely occluded by a firm gristle-like ring, the size and shape of a shelled peanut, encircling the whole of the pyloric ring. The radical operation was done, with good subsequent results.

L. J. CARTER, M.D.

Regarding the Measurement of the Tube Potential with a Sphere Gap in a Continuous High Tension Current Apparatus. Rudolf Thaller. Strahlentherapie, 1927, XXVI, 408.

The author draws attention to a number of precautions which have to be remembered when the tube potential is measured with the sphere gap parallel to the tube, chiefly in the case of apparatus delivering a continuous high tension current. It is essential that the order of magnitude of the high resistance in the circuit, the number of single sparks passing per second, and the capacity of the sphere are in a certain ratio. This is based on the exponential law governing the charging of a capacity over a high resistance.

E. A. POHLE, M.D.

A Clinical Evaluation of Cholecystography by the Oral Administration of Tetraiodophenolphthalein: A Summary. J. H. King and Lay Martin. Bull. Johns Hopkins Hospital, October, 1927, XLI, 219.

The material in this series represents 407 cases which were subjected to this test. Of this series, 62 patients were subjected to operation.

In the class of cases showing a normally functioning gall bladder, 20 cases were operated on. Eleven showed a normal gall bladder in the judgment of the surgeon at operation. The other 9 cases showed chronic cholecystitis, with stones. In this type of case the Graham test was found to be correct in 11 out of 20 cases.

In the type classified as abnormally functioning gall bladder there were 6 cases. In all of these cases a diseased gall bladder was found at operation.

In the type of case showing no dye in the gall bladder there were 36 cases, and at operation 30 cases showed a diseased gall bladder.

In the discussion of the cases the authors state that in the 9 cases showing a normally functioning gall bladder and in which microscopical examination gave definite evidence of cholecystitis, stones were found in all. This shows that the presence of stones does not preclude the normal concentrating function of the gall bladder and also that the association of stones and the absence of the gall-bladder mucosa will not prevent this concentration. They also state that the gall bladder can concentrate the dye in the total absence of mucosa and may fail to do so with this membrane normal, as shown by 3 cases of the one and 11 cases of the other. They believe that the number of stones demonstrated by X-ray after dye administration is decidedly greater than without it.

They conclude that the evidence reported by the Graham dye test must be carefully compared with the information gained from clinical studies of the cases under consideration. This is helpful but not absolute.

HOWARD P. DOUB, M.D.

Pregnancy after and during the Treatment of Uterine Cancer. Carl Karg. Strahlentherapie, 1927, XXVI, 286.

The author reviews in this paper seven cases of pregnancy in women who had been treated previously with radium for malignant disease of the cervix (5) and the vulva (2). Normal children may be delivered in such cases, and no signs of injury developed even later. Twelve patients received radium application during the term; in eight cases normal delivery took place, two had Cesarean section, and two aborted during the treatment. Eight children who were kept under observation developed normally.

E. A. POHLE, M.D.

Has the Time of Ovarian Irradiation Any Influence on the Beginning of the Amenorrhea? H. Weigand. Strahlentherapie, 1927, XXVI, 293.

Seitz and Wintz have advanced the hypothesis that there is a definite relation between the time of irradiation of the ovaries during the menstrual interval and the beginning amenorrhea. They assume, for instance, that in all probability the next period will not appear if the treatment takes place within the first two weeks after the last menstrual period. The author offers statistical material from the Gauss Clinic in Würzburg which seems to be at variance with the above theory. One possible explanation may lie in the fact that in his cases curettage was always done before the treatment to rule out malignancy. It is well known that during the climacteric this alone will often lead to amenorrhea.

E. A. Pohle, M.D.

The Roentgen-ray Treatment of Chronic Bone Fistula. G. H. Schneider. Strahlentherapie, 1927, XXVI, 303.

Chronic bone fistulæ were improved by radiotherapy. From 150 to 200 *R*, effective in about 3 cm. depth or 25 per cent S.U.D. on the skin, are recommended. The mode of action seems to be an indirect one.

E. A. Pohle, M.D.

Obstructive Lesions of the Gastro-intestinal Tract. Alfred J. Grant. Can. Med. Assn. Jour., October, 1927, XVII, 1149.

The author analyzes fifteen cases of intestinal obstruction which came to operation. This type of case carries a high operation mortality record, on account of the difficulty of diagnosis. This high mortality would be lessened if lesions which tend to obstruct were diagnosed and treated before obstruction supervened.

In this series 13 out of 15 had symptoms of chronic tendency to obstruction for years. Further, the causes of obstruction were found to be such conditions as duodenal ulcer and carcinoma of the stomach and bowel, conditions which were amenable to treatment, which would have obviated the grave crisis to which the patients eventually came.

In diagnosis, the X-ray is of the greatest aid. The barium enema is first used, followed later by the opaque meal.

L. J. Carter, M.D.

Influence of Thorium X on the Sedimentation Velocity of the Red Blood Corpuscles. Ibrahim Valeeff. Strahlentherapie, 1927, XXVI, 363.

The author injected Thorium X of varying strength into rabbits and studied the suspension stability of the blood. Small doses did not change the sedimentation speed of the red blood corpuscles at all, while large doses increased it considerably. This effect manifests itself one or two days after the injection.

E. A. Pohle, M.D.

Spontaneous Gangrene of the Extremities. Dean Lewis. Can. Med. Assn. Jour., October, 1927, XVII, 1125.

The author makes an analysis of 139 cases. Classified as to their etiological association they are divided as follows: Forty-seven arteriosclerosis, 43 arteriosclerosis associated with diabetes, 27 gangrene in diabetics in which arterial changes did not attract attention, 14 thrombo-angiitis obliterans, 1 scleroderma, 7 in which infection played the principal part.

Several excellent cuts illustrate various phases of the condition. Radiographs of specimens injected after amputation demonstrate occlusion of the vessels, lack of collateral circulation in arteriosclerosis, and well marked collateral circulation in thrombo-angiitis obliterans.

L. J. Carter, M.D.

Regarding a Method of Roentgenotherapy in Bronchial Asthma. N. A. Podkaminsky. Strahlentherapie, 1927, XXVI, 269.

The author has developed a new method of treatment of asthma with roentgen rays. He exposes four fields in the occipital region, ad-

ministering 25 per cent E.D. (4.0 Al., 22 cm. F.S.D., quality of radiation Bauer 7) over one field within a week. Eight cases have been successfully treated. Although no definite conclusions may be drawn from this material, the method should be given a fair trial.

E. A. POHLE, M.D.

The Roentgen-ray Treatment of Arthritis Gonorrhoica. H. Guhrauer. Strahlentherapie, 1927, XXVI, 275.

Twenty-eight patients suffering from gonorrheal arthritis (14 acute, 14 sub-acute cases) were irradiated over the affected joints. In the majority of cases, definite relief was secured. The pain subsided, the swelling went down, and the temperature dropped; in three cases there was no effect at all. Technic: 160–180 K.V., 0.5 Zn. plus 1.0 Al., 26 cm. F.S.D. several fields, 25 per cent E.D. per field, to be repeated every two weeks, not more than three times. Diathermy, salicylic acid medication, and mechanotherapy are recommended in support of the X-ray therapy.

E. A. POHLE, M.D.

The Erythema Effect of Different Qualities of Radiation as Based on Measurements in Roentgen Units with the Standard Instrument of Küstner. A. Determann, H. Jacobi, and H. Holthusen. Strahlentherapie, 1927, XXVI, 472.

A very careful study of the relation between wave length and the number of roentgen units required for an erythema dose leads the authors to the conclusion that the quality of radiation has no influence upon it. Their experiments cover a range of from 64 K.V. filtered through cardboard, half value layer in copper 0.06 mm., up to 186 K.V., 1 mm. copper plus 1 mm. aluminum, half value layer in copper 1.32 mm. It appeared that 630 roentgen units (field 3 × 3 cm.), 550 *R* (field 6 × 8 cm.), and 425 *R* (field 20 × 20 cm.) can be used as a safe mean value for an erythema dose. These findings are at variance with the figures published by a number of other investigators, who report a definite relation between quality of radiation and number of roentgen units required for an erythema dose.

E. A. POHLE, M.D.

Distant Charging Device for the Wulf Ionometer. E. Mühlmann. Strahlentherapie, 1927, XXVI, 624.

Description of the device permitting the charging of the ionometer from the control room.

E. A. POHLE, M.D.

The Duodenogram Applied to the Demonstration of a Duodenojejunal Diverticulum. J. Buckstein. Am. Jour. Surg., October, 1927, III, 340.

For examining the distal portion of the duodenum and the duodenojejunal junction, the author advises the use of a rubber tube, the distal 10 inches of which is perforated and has numerous openings. When by fluoroscopic control the tube can be seen to have reached the duodenojejunal junction, barium is injected, and this portion of the duodenum fills immediately. This can then be examined carefully without the overlying stomach being filled with barium.

The author believes that this will be useful in diagnosing duodenal diverticula and in differentiating these from perforating gastric ulcer pockets.

HOWARD P. DOUB, M.D.

The Roentgen-ray Treatment of Malignant Tumors, Combined with Dextrocid Injections. Henri Hirsch. Strahlentherapie, 1927, XXVI, 279.

Lewin published (in 1924) encouraging results with a combined intravenous injection of introcid (iodin-cer composition) and irradiation of malignant tumors. The author could not confirm these observations, and therefore experimented in search of a more efficient chemical compound. Based on the research of E. G. Mayer, who used a hypertonic glucose solution for the same purpose, a preparation was developed called "dextrocid," which contains glucose and iodin-cer. In ten out of

eleven cases of advanced malignant disease, this new medicament proved very effective.

E. A. POHLE, M.D.

Experiments with Roentgen Rays on the Hearts of Frogs. L. Haberlandt and R. Sandera. Strahlentherapie, 1927, XXVI, 607.

The authors offer the theory that hormones control the heart action. In order to study the effect of radiation on these hormones, they irradiated surviving pieces of frog hearts with 44 K.V., 4 ma., no filter, one-half hour corresponding to 20 H. During the exposure, the rate of beating increased, representing the positive effect of the radiation. Seventeen pieces which were at rest started beating on exposure and continued so during the irradiation; sometimes there was also a negative effect manifesting itself in the slowing down of the action, followed by a return to the former frequency. If the hormone was exposed *in vitro* its activity appeared to be lessened. This is taken as evidence that the hormones are protected while in the heart muscle and will not be affected by irradiation. The possibility of a beneficial effect of irradiation of the heart in cases of angina pectoris is considered.

E. A. POHLE, M.D.

Biological Effect of Roentgen Rays and its Investigation by Means of the Tissue Explantation Method. Martin Schubert. Strahlentherapie, 1927, XXVI, 425.

A number of investigators have studied the effect of roentgen rays on normal and pathological tissue. Following the example of Krontowski (See this Journal, 1926, VI, 363), the author experimented on heart tissue of chicken embryos with the explantation method. The radiation used was: 120 K.V. effective, 2 ma., half value layer (Christen) = 2.5 cm. E.D.: no filter, 20 cm. distance 2½ minutes, for 1 mm. aluminum, six minutes, for 3 mm. aluminum, nine minutes: also 10 K.V. effective, special type of tube with Lindemann window, 10 ma., E.D. at 10 cm. distance = ten minutes. The dose varied from one to ten E.D. The influence of cold to the freezing point was also investigated. Microscopical changes were studied, supplemented by spectroscopic examination and the measurement of the hydrogen ion concentration of the extract. All findings of Krontowski were confirmed. The examination of extracts frozen *in ova*, then irradiated, showed oxyhemoglobin indicative of hemolysis. The hydrogen ion concentration had shifted to the acid side. When using X-rays of extreme long wave length (10 K.V.) one has to differentiate between the effect of radiation and that of the gases formed. It was evident, however, that the radiation alone retarded the growth of the cultures. The X-ray effect influences the cells primarily; the change of the surrounding medium comes secondarily. Very important seems to be the change of the permeability of the cell membrane.

E. A. POHLE, M.D.

Regarding the Calculation of Measuring Results with the Michelson-Marten Actinometer. H. Pfleiderer. Strahlentherapie, 1927, XXVI, 630.

The method usually used for the calculation of Michelson-Marten actinometer values is, according to the author, not correct. He presents in this article a mathematical deduction showing how to reduce these errors to a minimum.

E. A. POHLE, M.D.

The Measurement of Therapeutic Light Rays. Hans Malten. Strahlentherapie, 1927, XXVII, 187.

This is a description of an electroscopic method of measuring light intensity emitted by a therapeutic lamp. Light rays strike an amalgamated copper plate connected to an electroscope, discharging this instrument. The drop of the leaf can be timed with a stop watch. The instrument is non-selective and gives an idea of the total intensity of a light source. For further details, the reader is referred to the original.

E. A. POHLE, M.D.

Some Practical Points in the Treatment of Ringworm with Thallium. J. H. T. Davies. Brit. Jour. Child. Dis., July-Sept., 1927, XXIV, 219.

The author in advocating thallium acetate to produce an epilation in the treatment of ringworm of the scalp, thinks it is superior to X-ray in that there is much less danger. There are no burns, no permanent alopecia, or even incomplete epilation, nor is there any possibility of damage to the brain.

Thallium is inexpensive and the dose accurate. However, he recognizes a number of disadvantages in the after-care of these patients, as the epilation does not occur all at one time and the lens and forceps are necessary to remove some of the remaining hairs. He has found no toxic effects in normal children. The presence of alopecia areata is a contra-indication for the use of thallium.

Dr. Davies gives 8.75 mgrm. of thallium acetate per kilo of body weight. The solution should be freshly prepared. A list of instructions is provided, with definite instructions relative to disinfection of material coming in contact with the head, washing of the hair, etc. Technic of treatment is given in detail in this article.

After epilation a 4 per cent iodine in spir. vin. rect. is painted over the infected area *t.i.d.* for four days, followed by Whitfield's or ung. sulphuris.

B. C. Cushway, M.D.

Septic Infections of Lungs and Bronchi. David A. Stewart. Based on a Study Made in Association with Joseph E. Pritchard and Edward L. Ross. Can. Med. Assn. Jour., October, 1927, XVII, 1116.

Septic broncho-pulmonary infections form about 40 per cent of all admissions to the Manitoba Tuberculosis Sanatorium.

Chronic bronchitis is usually bronchiectasis, and bronchiectasis is not a rare, but a common, condition. The common causes are septic mouth, nose, and throat conditions; the acute respiratory diseases; aspiration of infective material during a general anesthesia, and an empyema discharging through lung and bronchi. The causative organism is usually some form of spirochete.

The course of septic infections of lungs and bronchi is usually chronic, but may at times be acute. The average duration of symptoms in sixty cases examined was five years. Complicating illnesses during the course of the disease averaged four for each person.

The diagnosis is by bronchography. Iodized oil is as necessary in the study of the bronchi as barium is in the study of the intestines. It is easily given. It may be tipped over the epiglottis into the trachea by a suitable syringe, or even deposited on the base of the tongue and aspirated or allowed to trickle down.

The first essential in treatment is to remove the cause. This may be infected teeth, pyorrhea, infected sinuses, or diseased tonsils.

In the early stages the main reliance is placed upon complete rest in bed over an extended period of time. Heliotherapy is a help. Postural drainage of the bronchiectatic sacs is useful. Neosalvarsan is a rational procedure to destroy the spirochetes. Autogenous vaccines act better after a course of neosalvarsan. Iodized oil, as a therapeutic agent, has been found by some to be of benefit, while others doubt its value, and even fear it may do harm. Surgery offers promise in advanced cases. Pneumothorax, thoracoplasty, and phrenicotomy, by collapsing the lung, lessen symptoms, and sometimes effect a cure.

The last stage requires desperate measures. The actual cautery has been used, with better results in lung abscesses than in bronchiectasis.

The best cure, however, is prevention. Better mouth care, and a longer convalescence from acute respiratory diseases, are important preventive measures.

L. J. Carter, M.D.

Progress with the Construction and Use of a Portable Standardization Instrument. Hans Küstner. Strahlentherapie, 1927, XXVI, 397.

This is a description of a smaller and portable instrument for the calibration of roentgen apparatus in roentgen units. For details, see the original article.

E. A. Pohle, M.D.

The Dependence of the Doses in Roentgen Units from the Average Wave Length as Compared with Equivalent Erythema Reactions of Roentgen-ray Qualities Used in Therapy. P. Hess. Strahlentherapie, 1927, XXVII, 146.

In this article the author offers the results of his investigations regarding the relation between the number of roentgen units required for an erythema and the quality of the radiation. A so-called standard erythema equal to 500 *R* (without back scattering, ionization chamber in air) for a large field of 20×20 cm. formed the basis of his experiments. It appeared that 40 per cent more had to be administered to get the same degree of reddening on a small field of 1.5×1.5 cm. (Technic: 180 K.V., 0.5 Zn. plus 1.0 Al.) Similar fields were exposed on the same patients, using different qualities of radiation with varying doses, until an equal amount of reddening was secured as compared with the standard erythema.

(Technic: Quality I. 185 K.V., 1.0 mm. Cu. plus 1.0 mm. Al.;
Quality II. 180 K.V., 0.5 mm. Zn. plus 1.0 mm. Al.;
Quality III. 145 K.V., 3.0 mm. Al.;
Quality IV. 110 K.V., 2.0 mm. Al.;
Quality V. 110 K.V., 1.0 mm. Al.;
Quality VI. 60 K.V., 0.5 mm. Al.;
Quality VII. 60 K.V., no filter;
Quality VIII. 9 K.V., no filter.)

Observations of the erythema between the fifteenth and twentieth day following the exposure show for Qualities I – VII that there is a dependence of the number of roentgen units required for the erythema from the average wave length. The difference is so small that if the roentgen values are compared (primary energy without back scattering), equal roentgen values correspond to equal erythema reactions within plus or minus 10 per cent. Between 60 – 9 K.V., there is first a drop of the number of roentgen units for the erythema, followed by an upward slope in the range of the very long wave length.

E. A. POHLE, M.D.

A Case of Recurring Sarcoma. W. A. Wilkins. Can. Med. Assn. Jour., September, 1927, XVII, 1058.

A girl of ten years, while skating, hurt her right shoulder. Eighteen months later she was admitted to hospital for a swelling on the right clavicle. X-ray examination showed the inner portion of the outer third of the clavicle to be expanded, the cortex being thin, irregular, and perforated. The clavicle was removed, and the pathological report was "rapidly growing periosteal sarcoma."

Three years later radiograph of the skull showed three areas of metastasis. Under X-ray treatment—mild epilation dose, in divided doses—the tumor disappeared.

Six months later the fifth dorsal vertebra became involved. The symptoms cleared up under X-ray treatment.

Three months later the pelvis became the site of metastasis. This again cleared up under X-ray treatment. At this time radiographs of the skeleton revealed no other areas of metastasis.

Six months later the tumor recurred in the skull, and was treated by the X-ray, with disappearance of the growth.

At a subsequent period routine radiographs showed metastatic growths in the left hip, the fourth lumbar vertebra, and the skull.

The striking features of this case are the frequent recurrences and their amenability to treatment by moderate X-ray doses.

L. J. CARTER, M.D.